MEMOIRS

OF THE

GEOLOGICAL SURVEY

OF

INDIA.

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INTRODUCTION.

MEMOIRS OF THE GEOLOGICAL SURVEY OF INDIA,

VOL. XV, Pt. 1.

AURUNGA AND HUTAR COAL-FIELDS.

ADDENDA AND CORRIGENDA.

Page 8, line 11 from top, *for* "Mirial" *read* "Miral."
Pages 13 & 14—The notes *a* at foot are transposed.
Page 29, line 6 from top, *insert* "in" after "participated."
" 30, line 4 from bottom, *for* "Lower" (group) *read* "Raniganj."
" 37, line 16 from bottom, *insert* "*the*" after "West of."
" 45, line 2 from top, *insert* "*the*" after "in."
" 50, line 15 from top, *dele* "as has already been mentioned."
" 50, note *a*, *for* "*dherbur*" *read* "*dherhur*."
" 81, line 16 from bottom, *for* "borings" *read* "holings."
" 82, line 9 from top, *for* "Mariatu" *read* "Masiatu."
" 111, line 2 from top, *for* "Valatile" *read* "Volatile," and line 11 from top, *for* "Dansi" *read* "Dauri."
" 112, line 11 from top, *for* "brownish" *read* "brown."
" 117, line 14 from top, *for* "Chipars" *read* "Chiparo."
" 125, line 4 from top, *for* "west" *read* "east," and line 11 from top, *for* "Sattarwah" *read* "Sat-Barwah."

ILLUSTRATIONS.

MAPS.

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MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA.

ON THE AURUNGA AND HUTAR COAL FIELDS AND THE IRON ORES OF PALAMOW AND TOREE, *by* V. BALL, M.A., F.G.S., *Geological Survey of India.*

INTRODUCTION.

ABOUT fifty years have elapsed since attention was first directed by Mr. A. Prinsep to Palamow, the object being to open out the coal fields then known to exist, and so obtain a supply of cheap fuel for the steam navigation of the Ganges. It was urged that an immense saving would accrue to Government by the establishment of a coal depôt at Futwah, only a few miles from Patna, which would feed all the more western stations on the river.

Daltonganj field worked by Bengal Coal Company.

To meet this demand the Daltonganj field was worked by the Bengal Coal Company up to the time of the mutiny, when the works were attacked by the rebels and destroyed. Since then coal has been mined, or rather quarried, to a small extent for the supply of the irrigation head-works at Dehree on the Sone, and for the supply for local purposes of some of the nearer towns in the vicinity of the East Indian Railway. During

Field not worked at present.

the past few years operations have, however, been in abeyance, owing to the cessation of these local demands.

Proposed branch line of railway.

The main canal having been completed, the questions have recently arisen, first, whether, by connecting the Palamow fields with the East Indian Railway by means of a branch line, or by a branch line and canal combined, a considerable saving in the price of coal, as compared with the cost of that carried from Karharbari, could not be secured for north-western stations; second, whether the Palamow subdivision does not offer facilities for the manufacture of iron on the European system.

Preliminary information required.

A definite estimate of the probable amount and the quality of the coal available, and an examination of the circumstances under which the iron ores known to exist occur, being preliminary data of great importance in this enquiry, it was determined last year that the geological examination of the area should be resumed, in continuation of Mr. Hughes' work on the Daltonganj field.

Area examined.

The Palamow subdivision with the adjoining parganah of Toree, which geographically and geologically belongs to it, though it does not do so fiscally, occupies an area of about 4,272 square miles. To geologically examine the whole of this tract, with a degree of detail which would be exhaustive and of permanent value, would occupy several working seasons. It was therefore considered advisable to make the examination of the coal fields the principal object of the season's work; while by making long traverses across the main area of metamorphic rocks, the principal iron localities could be visited, and a certain amount of negative, if not of positive, evidence could be obtained regarding the possible existence of hitherto undiscovered basins occupied by sedimentary rocks.

Existence of two distinct fields ascertained.

The result has fully justified this disposition of the available time. The so-called Upper Coal Field[a] has been found to resolve itself into two distinct and separate fields which contain very different qualities of coal; which information,

[a] It is to be hoped that this ambiguous and misleading title will not be again employed by any one who may have to write of these fields.

and that which has been obtained regarding the various iron deposits, will probably be considered sufficient to determine the questions as to the projected establishment of an iron factory and the selection of the best route for connecting the district with the East Indian Railway.

Iron ores.

For reasons that will be given on subsequent pages, the titles Aurunga and Hutár have been adopted to indicate in future these two areas of coal measures and their associated sedimentary rocks.

Titles of fields.

Although it will be necessary to describe each field separately, the preliminary chapters in this account, which refer to previous observers and to the general physical features and geological structure of the surrounding country, will be common to both. This is not merely a matter of convenience, but is rendered necessary from the fact that the existence of two distinct fields was not apparently realised by any one who has hitherto written on the subject. Further, the advantage of describing the physical features in one continuous account is sufficiently obvious. For very much the same reasons, the concluding chapter on the economic resources will refer to both fields and also to the surrounding area of crystalline rocks, since it will thus be easier to treat as a whole the comparative and general aspects of the conditions under which the coal, iron and other minerals occur, their value and availability. It is therefore the purely descriptive geology of the fields alone which it will be necessary to submit to separate treatment and description.

Arrangement of subjects.

CHAPTER I.

PREVIOUS NOTICES.

Rennell, J., F.R.S., Atlas, 1781.

In Rennell's map of the "Conquered Provinces on the South of Behar" (No. VIII), we find "Cole mine"[a] marked on a spot, which, from its relative position to the Coyle (Koel) river and the villages of Chopere (Chapri) and Coruna (Karunkhora), may confidently be identified with Hutar. This particular map is dated 1779, so that the discovery of the field took place at least a century ago, and long before the fields in many more accessible localities were brought to notice. It is not improbable that the fact of its being in the neighbourhood of the Palamow Fort may have attracted attention to it. Under these circumstances, the propriety of adopting the name of the village Hutar to indicate the coal field will not be disputed.

Sage, Captain, 1830.[b]

In the year 1830 the Hutar field was visited by Captain Sage, who gives a section of the coal seams and associated rocks which occur at the junction of the Dauri and Ghorasan rivers as follows:—

	Ft.	In.
Earth, sand and gravel	8	0
Sandstone	6	4
Shale (bituminous)	1	0
Ditto	2	1
Coal	1	1
Shale	1	0
Sandstone	1	4
Coal	3	9
	24	7

[a] This is also marked on Arrowsmith's map for 1804. The locality was visited by Captain Franklin in 1829. See "Gleanings in Science," Vol. I, p. 178, and Vol. II, p. 217.

[b] "Gleanings in Science," Vol. II, pp. 219, 220.

He speaks highly of this coal as being very bituminous and burning with a clear bright flame. It has been supposed that the coal spoken of as being of inferior quality by Mr. Smith (*vide postea*) was the same, but this I do not think to be the case. I shall show on a subsequent page that there are several distinct outcrops of coal in the Dauri section.

Captain Sage also visited the 'coal mine' at Hutar, and in the Burra river close by discovered extensive beds of coal on the left bank. I do not know to which of the streams the name Burra was applied. If it be the one at Hutar, the term *extensive* is certainly applicable to the seams in a sense, as the lateral extension is considerable; but the thickness it will be seen is trifling.

Ironstone is said to be plentiful in the neighbourhood of Alyapur, three miles south, where it is worked. The name Alyapur is unknown to me, but ironstone does occur about three miles south of Hutar. Captain Sage's remarks on the navigability of the Koel I shall again allude to.

Homfray, J., 10th July 1837.

In the year 1837 Mr. J. Homfray was deputed by the Coal Committee to report on the coal fields of Palamow. He says[a] :—

"At a ford near Mungardar Nuddee on the river edge, four or five thin bands of coal, from four to twelve inches in thickness, but no thick vein; near to this place is Hutar, and this is conjectured to be the site of Rennel's 'Cole mine,' since there is no other place in the river for some miles where coal is to be found, until we reach the small nuddee of Barwellia running to the eastward; and at half a mile up that stream there is a fine vein of coal three feet four inches thick. This coal is found also to the westward at Myapore, and indeed for an immense distance southward and westward; it is traceable even down to Singhbhúm and towards Ruttenpur—this I learnt from an intelligent zamindar with whom I was in company for three days—so also to the eastward; and this is what constitutes the Palamow coal field. Within the Barwellia Nuddee this vein of coal is three feet four inches, exclusive of some little adhesive black shale which makes the apparent thickness of the vein to be four feet six inches. Both sides of this Nuddee are very high sandstone hills, and underneath which the coal is traceable to the eastward and northward, continuing to crop out in a vast number of places until

[a] Coal Committee's Report, 1846, p. 159.

we bring it fairly over to the Dauri Nuddee, the upper end of which winds into an extraordinary deep and narrow valley, within which this vein, as well as another smaller one of one foot six inches lying at five fathoms beneath it, is found."

Mr. Homfray after a description of the valley goes on to say that he raised 700 maunds of this coal, and states that—

"It burns with little flame, gives out an intense heat, with very little or scarce any smoke; it retains fire for days together; and to me appears to be a stone coal."

Inaccuracies in the above.

I should have preferred to have given a *résumé* of Mr. Homfray's remarks as a whole, rather than quote the above rambling statement; but I find it quite impossible to follow a large portion of his description. Some of the localities he mentions are quite unknown to me, and on the others the remarks are either vague or inaccurate; particularly, however, is it necessary to call attention to the statement made about the coal extending to Ratanpur and Singhbhúm on the authority of an intelligent native. If for Singhbhúm we read Sirguja, the statement would be consistent with general accuracy. But as Singhbhúm is again referred to by Mr. Homfray, and his statement has been quoted in subsequent publications, it is necessary to point out that a Singhbhúm coal field had its existence only in the imagination of his intelligent friend. Detached areas of coal measures do, however, extend towards Korba and Ratanpur through Sirguja and adjoining territories. In the Committee's Report, Mr. Homfray's estimate of the extent of the field is stated to be fourteen miles by six miles, which would be a fair approximation to the truth; but in his own letter he seems to claim a wider extension "*over an immense extent of country.*"

Koel unsuited for navigation.

He points out very clearly the impossibility of employing the Koel above Chandu as a means of carriage, but somewhat exaggerates the difficulties of the route by road, as the Ghâts he speaks of can be avoided.

Iron.

Regarding iron he writes—

"Ironstone is here found in abundance close to the village of Baumundya in the Dauri Nuddee in veins of three and four inches each; these veins are also found in

the ravines all the way to Pohea Agar (Pootooagur of present map), and at which place there are a number of iron melting furnaces upon the native plan. Iron is here sold generally at Rs. 2-12 to Rs. 3 per maund of 48 sicca-weight seers; it is in lumps of four to five pounds each, and has undergone the process of hammering and re-melting four times at the time of sale."

Mr. Homfray concludes with a mention of the "*extraordinary fact*" that—

"the gigantic reed whose impressions we constantly discover in the carbonaceous strata is here found growing in luxuriance. I have brought some whose roots were actually extended four feet into the coal bed. This is the only example I know of the living reed being found near to coal."

In Dr. McClelland's Report we are told that the specimens were exhibited at a scientific *soirée* at Government House, as belonging to the plant from which coal is derived. Subsequently, they were found to be only a well-known-grass, *Saccharum spontaneum,* which grows very generally throughout Bengal. Possibly to this *exposé* of his discovery may be attributed some of the bitterness of Mr. Homfray's remarks upon the "literary phantasmagoria" of "snail hunters" and "saxoflorists" which appears in his paper on the coal-field of the Damuda Valley[a], where he very properly points out the absurdity of the theories which were current as to the former connection of the Damuda and Sylhet coal fields.

Ravenshaw, E. C. Letter to Secretary, Government of Bengal, dated 6th January 1840[b].

In looking over the past history of discoveries of coal in Palamow, I find several allusions to a reputed discovery of coal at a place called "Chupri, two koss south of the Sone river, before its junction with the Koila Nuddee."

Reputed discovery of coal at Chupri.

Properly speaking, this locality is quite outside the area under description; but owing to the fact of its proximity to the head works of the canal and to the occurrence of quite another place with the same name close to the Hutar field, I think it not altogether inopportune to give here

[a] Journal, As. Soc., Bengal. Vol. XI, p. 724.

[b] Reprinted in Mr. Forbes' Settlement Report of Palamow.—Calcutta, 1872.

the result of my inquiries. As the locality is not given in the coal Committee's Report printed in 1846, it may be that the true history was at that time known to the Committee; but nowhere can I find any published statement of the real facts as given below.

According to Mr. Ravenshaw's letter, the discovery at the above-named locality was communicated to him by Cazi Mahamdee of parganah Jupla—

"The specimen of coal forwarded from this mine appeared precisely similar in quality to that from the Singra mines; but after digging a hundred maunds, the coal is stated to have assumed a more stony character, and the Cazi therefore abandoned the mine and proceeded to the old mines of Singra and Mirial near the banks of the Koila Nuddee."

The remark on this made in Dr. McClelland's Report on the coal fields of India, dated 11th July 1845[a] is as follows—

"If the Cazi's statements regarding the existence of coal so near the Sone be correct, the circumstances under which it occurs ought to be fully investigated."

Although the neighbourhood is included in the Geological Survey Map published in 1869, the position of one village named Chupri being represented as surrounded by alluvium, and although the account of the Cazi's operations was strongly suggestive of deception, it seemed to me all important to thoroughly enquire into the story and, if possible, expose and stamp out the fiction, or establish the fact, as the case might be. Being somewhat pressed for time towards the end of the season, and unable personally to visit the locality, I was fortunate in being able to refer to Mr. Davies of Rotasgurh, from whom I received the following letter, which will probably recall to some readers of this similar stories of reputed coal discoveries in other parts of India. Mr. Davies writes—

Mr. Davies' letter.

"That olden report concerning the discovery of coal at Chupri, not far from Deori was a pure fabrication and got up by the then Cazi of Jupla to try and ingratiate himself with the Bengal Coal Company and benefit by working on their apprehensions. The matter was closely enquired into

[a] Printed by order of the House of Commons, 19th June 1863, and reprinted, in so far as it refers to Palamow, in Mr. Forbes' Settlement Report.

by a gentleman named Sweetland, with whom I was well acquainted. He was on the staff of the very first explorers in India on account of railways, and was practically acquainted with geology. The other Chapri to which you allude is, as you observe, located on alluvium. A report similar to that got up by the Cazi was spread abroad by a *lohar*, or blacksmith, in the vicinage, shortly before Dr. Hooker came to Rotas, and Mr. Williams (Government Geologist), in company with Dr. Hooker, explored the Bhukhi *Kho*, or valley, in consequence fruitlessly. I subsequently discovered that the *lohar* had purposely scattered fragments of Rajharra coal in the dry bed of the Bhukhi *Kho* to give a color to his assertions."

Dr. Hooker in his journal does not make any reference to this in his account of his visit to Rhotas, but alludes to the information and assistance he received from Mr. Davies.

Smith, D., 1856.[a]

In his Report on the coal and iron of Bengal, Mr. Smith, having described the coal field in the neighbourhood of Rajharra, gives an account of his observations made during a rapid trip southwards into the Hutar field. He appears to have met with but one seam, which occurs in the Dearee (Dauri) Nuddee at the foot of a hill named Chenra. It is described as being two feet two inches thick and of very inferior quality. His further remark that—

"the strata here have a 'dip' to the west, which is unusual *and may be taken to indicate a serious disturbance in this coal field*"—

shews a certain want of appreciation of the laws of legitimate geological induction; but otherwise I see nothing to justify a recently-printed criticism of Mr. Smith's Report. On the other hand, in dealing with the question of iron manufacture, his full mastery of his subject is abundantly apparent. What he wrote in 1856 might be read with advantage by promoters of iron works to-day[b]

Ill health prevented further exploration of the area, and the principal coal deposits were not seen by him. But he was fully satisfied that the

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[a] Report to Government of India on the Coal and Iron Districts of Bengal, dated Nynee Tal, 1856.

[b] A reprint of Mr. Smith's Report will be found in Dr. Oldham's, "Return on the Coal Resources and Production of India."—Calcutta, 1867.

heavy cost of transport and the bad quality of the coal—

"deprived this locality of all chance of successful competition with others more favourably circumstanced."

It will be found that the conclusions I have arrived at, even under the somewhat altered conditions of the present day, are in many respects similar.

On his return journey northward, he reports the occurrence near the village of Adur of a—

"deposit of magnetic iron ore of the very richest quality, but so limited in quantity as to be of no importance."

Hughes, T. W. H., 1872.[a]

Appended to his Report on the Daltonganj field, Mr. Hughes gives a note on the sedimentary rocks observed by him at Satbarwah, where he only saw Talchirs, and in the neighbourhood of Latiahar, where he remarked upon the presence of Barakars and Upper Panchets (Mahadevas). He states that there is but little coal, and notes the ferruginous character of the Barakars in some sections.

Forbes, L. R., 1872.[b]

Mr. Forbes' Settlement Report embraces a wider range of topics and contains more interesting information than is to be found in many similar publications. The first chapter on the physical features contains most of the information immediately connected with the present subject, but from several of the other chapters numerous facts bearing upon the future development of the country may be gleaned. The whole cannot fail to be instructive to any one who may be at present, or is likely to become hereafter, connected with the exploitation of the resources of Palamow.

Mr. Forbes describes the general structure of the area, and points out that the forms of the hills are directly due to the character of the rocks of which they are built up. He then enters into some rather

[a] Memoirs, Geological Survey of India, Vol. VIII, p. 22.

[b] "Report on the Ryotwaree Settlement of the Government Farms in Palamow" by L. R. Forbes, Esq., Assistant Commissioner and Settlement Officer.—Calcutta, 1872.

original speculations as to the origin of the crystalline rocks, and attributes, as others have done before him, the splitting-up and fracture of the gneiss, &c., to the sudden transitions in temperature during the winter months. I believe this agency to be wholly incapable of producing the results. Owing to the feeble conducting powers of stone, the temperature of the atmosphere can only affect but a limited superficial layer of rock; moreover, with a sudden fall of temperature, the stone is not immediately cooled, but gradually radiates forth its heat, which process may be continued throughout the greater part of a night, as any one who has camped near bare rocks during the hot weather is likely to have a lively recollection of.

Mr. Forbes shews the accuracy of his powers of observation by pointing out the existence of detached patches of sedimentary rocks at a distance from the main areas.

He then describes the coal-mining operations in the Daltonganj area, and discusses the question of a light railway to connect the field with the East Indian line.

The discovery of copper ore by himself in Daltonganj is recorded, and there is an interesting sketch of the native system of manufacturing iron, to which reference will be made on a future page.

Mr. Forbes alludes to the coal of the Aurunga valley, of which he appears to have been the first discoverer.

In an appendix, the reports on the coal by several of the above authorities are quoted in full, the whole forming a valuable epitome of the information available on the subject up to date.

Samuells, Captain, 1871-72.[a]

In his descriptive accounts of the country surveyed in Districts Hazaribagh and Lohardugga during the season 1871-72, Captain Samuells mentions the seams at Jugguldugga as containing, apparently, the best coal. Several localities

[a] "Report on the Revenue Survey Operations of the Lower Provinces from October 1871 to September 1872.—" Calcutta, 1873.

where coal occurs in parganah Toree are also marked on his maps. The coal of the Amanut and Damuda is alluded to.

The area occupied by the coal fields is roughly estimated at 1,500 square miles. Including the Karanpura fields, this is about double the actual area, but was no doubt arrived at by supposing that the most remote localities formed part of one connected area. An account of some hot springs in Hazaribagh is also given by Captain Samuells.

Memoirs on Branch Line by P. W. D.

Some papers which have been printed by the Public Works Department, in connection with the proposed branch line of railway, contain a *résumé* of the information on the coal fields which is given in some of the reports above quoted. As these documents I believe have not been published, they are not susceptible of criticism here. But what has been said on the previous pages will shew the value of some of the statements which have been thus reproduced.

CHAPTER II.

PHYSICAL FEATURES.

SECTION 1.—GENERAL STRUCTURE OF THE AREA.

Limits of area here described.

THE portion of Palamow herein described and the parganah of Toree are situated south of the Daltonganj parallel of latitude. To define the tract more exactly, it may be said to coincide with the rectangular area which is bounded by the 83° 45′ and 84° 45′ meridians of east longitude, and the 23° 30′ and 24° parallels of north latitude.

Central valley crossed by a watershed.

In the central part of this area there is a distinct valley which is on the same line of east and west strike as the Damuda valley, but is separated from that line of drainage by a very marked bar of metamorphic rocks which forms a watershed separating the waters which flow northwards, by the Koel and Sone, into the Ganges from those which find their way eastwards by the Damuda into the Hugli and so into the Bay of Bengal.

Disruption of coal fields how produced.

Separated by this barrier at an average distance from each other of six miles, lie the coal fields of Karanpura and Aurunga. That these two areas formed at one time parts of a continuous whole, there can be little doubt; and the relative elevations of the two fields compared with that of the watershed, considered in connection with some other observations, indicate pretty clearly the *modus operandi* by which the disruption was produced. The marginal rocks of the Karanpura field dip away from this watershed at elevations only slightly below its average level, while outlying patches of beds of the same age occur at even higher levels. It does not seem probable, therefore, that the barrier is formed, at least to any great extent, of a locally upheaved ridge[a]. On the other hand, the

[a] Mr. Medlicott found rocks which he considered to be of this age capping the Madagir Hill near Toree.

Aurunga field is at Rampur on the eastern margin 300 feet, and at Latiahar, if the elevation given on the map be correct, more than 600 feet below the watershed at Balumath. But when we find outlying patches of the Barakar rocks at elevations of from 150 to 200 feet higher than the neighbouring parts of the Aurunga field, and other patches which there is good reason to believe exist at still higher elevations in the highlands on the south-east and south,[a] we are compelled to suspect that the Aurunga field has subsided as a whole. That such has actually been the case seems to be incontestibly confirmed by the intense faulting and tilting of the beds in that field, as is indicated on the map, and will be fully described on a future page.

Hutar field let down by faults.

Similarly, the Hutar field shews evidence of having been let down towards the west by faults, which have tended to isolate it and alter the pre-existing general directions of the drainage. There is, however, much less lithological resemblance as regards the lower groups of rocks between the Hutar and the Aurunga fields than there is between the latter and the Karanpura, and there is therefore less ground for assuming an original continuity, though such may possibly have existed.

Without trenching on the subjects which belong strictly to subsequent sections, it is impossible to enter here more fully into this part of the question. But so much, as affording a preliminary view of the origin of the present structure, was necessary to make what follows intelligible.

Central valley originally continuous with the Damuda valley.

This central Palamow valley, then, was probably originally continuous with the Damuda valley separating the Hazaribagh plateau on the north from that of Lohardugga or Chutia Nagpur on the south.[b] Towards the

[a] The disturbance and tilting of some of the beds on the margin of the Karanpura field perhaps indicates some upheaval, but may, on the other hand, be due to lateral pressure from within.

[b] The origin of the valley as a whole, which is a distinct question from its separation into two, will be treated of on a future page in the section on the rocks of Mahadeva age.

valley of the Koel the former disappears, but the latter is continued by ranges, *páts* and highlands generally through Sirguja and far away to the west.

Characters of scenery.

As the hills and rivers are described under separate sections below, it only remains to refer to the general aspect of the area. The scenery is very varied, often beautiful, and occasionally grand. Flat plains of wide extent are of rare occurrence. But the forest-clad hills, the bold scarps in the highlands formed of sandstone, the rocky beds and rapids of the principal rivers, and the lofty ranges which bound the view on the south, all combine to produce most pleasing effects. Though tolerably familiar with most parts of the wide area of Chutia Nagpur, I have seldom come across a scene more attractive than that presented to my view as I entered the Aurunga valley in December. Particularly striking were the effects produced by the patches of many-tinted cultivation scattered about through the more uniformly coloured jungle which surrounds the irregularly outlined Jugguldugga and Latiahar sandstone ranges. There were scarcely any bare spots to be seen, and though the previous rainfall had been lamentably insufficient for some of the crops, but little evidence of the drought was to be seen in the greenery and brightness of the jungles at that season.

Aurunga valley.

Section 2.—Hills.

The hills of this area are susceptible of a triple classification which is determined chiefly by the geological structure—

1st.—The oldest and most numerous are those formed of the crystalline or metamorphic rocks.

2nd.—Those formed of sandstones or conglomerates.

3rd.—The *páts*, or plateaux, which are formed of crystalline rocks, with their summits capped with sandstone trap or laterite.

The 1st class is represented by a great number of hills and ranges, with elevations up to, and sometimes beyond, 3,000 feet. Where not

capped by any of the above-mentioned more recent formations, the outlines presented by these crystalline hills are generally sharply angular, but some of the ridges are flat-topped and continuous at pretty steady elevations for long distances.

Hills of crystalline rocks.

2nd.—The hills of this class are exclusively formed of one or other of two of the subdivisions of the Gondwana sequence, *viz.*, Barakars or Mahadevas. In the Aurunga field the Barakars never rise to form an eminence worthy of the title of hill; but in the Hutar field, east of the Koel river, they form long ranges averaging from 250 to 300 feet above the surrounding country, occasionally having peaks which rise about 200 feet higher. This occurrence of Barakars as hill-formers is unusual and will be again alluded to further on.

Hills of sandstones, &c.

Barakar hills.

Rocks of Mahadeva age occur as hill-formers not only in the Aurunga and Hutar fields, but also in the Karanpura and Tatapani fields. The structural and lithological characters in each case present the closest and most striking points of resemblance. In the Aurunga field there are three distinct groups of these hills, which are situated respectively in the neighbourhoods of the villages of Subano, Jugguldugga and Latiahar. Besides which there are two small outlying hills at Sasung and at Chulta west of Latiahar. These groups consist, for the most part, of flat-topped ridges from 200 to 300 feet above the level of the surrounding country, and have their faces scarped and often eroded into grotesque shapes. Occasionally, where the beds have been tilted, conical peaks rising considerably above the general level of the ridges have been formed, as, for example, the Chiharo peak near Subano, and the Latiahar peak near the village of the same name. The latter hill according to the map is 910 feet high, or 2,051 feet above the level of the sea.

Mahadeva hills.

In the Hutar field there are similar flat-topped ridges with scarped and eroded faces. In this area the Bijka hill is the most prominent peak, being 1,300 feet above the village of the same name, or 2,479 feet

above the sea. In its vicinity are several subordinate peaks, all of which owe their elevation in a measure to the tilting of the beds caused by the faults which bound the field.

Pâts: crystalline hills capped by trap, laterite, &c.

3rd.—Regarding the pâts which occur on the south of the area, what little is known of the details of the caps which give them their peculiar character will be found on a following page. The principal are Neturhat 3,600 feet; Lamti pât 3,777; Gulgul pât, 3,823 feet; Jamira pât, and Mailan pât, 4,024 feet. Besides these pâts, from the contours of some of the hills near Balumath, I think it probable that they will be found to be capped with sandstone. The Madagir hill, near Toree, was found by Mr. Medlicott to be capped with sandstones, which appeared to him to be of Barakar age. North of the Hutar field, near Bansdih, the Chungah hill is capped by a curious arkose bed which forms a small plateau.

Other capped hills.

As to the age of this rock, I am quite uncertain, owing to its very local lithological characters. For the present it must remain unrelegated to its position in the geological sequence.

SECTION 3.—RIVERS.

Rivers afford evidence of great denudation.

The principal rivers of our area are the Koel,[a] the Aurunga, the Sukri and the Kunhur. The most remarkable feature exhibited in common by the Koel and Kunhur is that their courses run north and south, or at right angles to the valleys in which the coal-fields are situated, thus indicating an enormous amount of denudation, since the direction must have been determined when the valleys were filled up to the level of the bounding ridges through which these rivers have cut deep gorges.

[a] I adopt this mode of spelling the name, as it more nearly, I believe, represents the ordinary native pronunciation than any of the numerous other combinations of letters which have been used by different writers, *e. g.*, Coyle, Koyle, Coil, Koila and even Côl.

Length and size of basin.

The Koel.—This river takes its rise in Burwah, another river of the same name also rising near the same spot, but proceeding southwards, to contribute to the formation of the Brahmini. This northern Koel is from its source to its junction with the Sone about 160 miles long, and since it drains a catchment area of at least 3,500 square miles, it naturally contributes a large supply of water to the Sone during the rains; but at other times the quantity is not sufficient to enable cargo boats of the smallest dimensions to make their way between Daltonganj and the Sone.

Koel not navigable.

At one time it was proposed (by Captain Sage in 1830) to make use of this river as a means of conveying coal from the Hutar field to the Sone. But any one to whom an opportunity had been afforded of actually seeing the rocky bed and rapids which are found between Chandu and Hutar could not have failed to denounce the scheme as an utterly chimerical and impracticable one. In any discussion as to the means which may be employed for bringing the Hutar coals to market, the navigation of the Koel as it now is, or even the canalization of it, may, I think, safely be left out of consideration.

It may be that the construction of a canal, fed by the head waters of the Koel, is possible; but so far as I know the ground, I believe that it would be attended with most serious difficulties, owing to the fact that the only outlet northwards is that of the Koel valley, which is in places so much constricted by impinging ranges of hills, that a low, level canal could scarcely be made so as to be safe from floods.

Scenery on Koel.

In many places this river affords scenes of very great beauty and sometimes of grandeur. The rocky bed and the rapids a few miles north of Hutar—the neighbourhood of Sindhorwah, where the river has scarped the hills of Barakar rocks which rise frowning over the channel and the rapids near Purro, beyond the southern boundary of the field—may be quoted as instances in point.

The Aurunga is the only considerable tributary of the Koel within our limits. It rises near Soheda in the pass descending from Lohardugga into the valley, and pursues a winding course in a north-westerly direction for a distance of about 50 miles. Where it traverses the coal field it affords numerous and instructive sections. Leaving the coal field, its bed rapidly widens, and by the time it reaches Palamow, where the ruins of two considerable forts overlook it, it has attained a considerable size, and, with its channel crowded with huge masses of gneiss, affords some very beautiful scenes. Owing to its rocky bed in this neighbourhood, its navigation would be dangerous during the rains. At other seasons the supply of water is insufficient for even the smallest craft. Its principal tributaries are the Sukri and Ghugree, both of which traverse portions of the field.

The Kunhur.—This river is in many respects similar to the Koel; it is about the same length, and pursues a nearly parallel course, to the Sone. It is likewise, at least in its upper reaches, useless for purposes of navigation. For a considerable portion of its course it constitutes a well-defined boundary between Palamow and Sirguja.

Section 4.—Hot Springs.

In each of the separate areas described in this report, and in direct connection with lines of fracture which it will be shewn have been instrumental in determining the present structure of the coal fields, there are series of hot springs.

Hot spring at Jarum.

The first of these is in close proximity to the Aurunga field; it is situated in the bed of the Tataka River at Jarum, about a mile and a half north-west of Pochra, or in north latitude 23° 49′ and east longitude 84° 32′. Although the water actually finds its way to the surface through joints in some vertical beds of granitic gneiss, which are the only rocks exposed in that part of the bed of the river, the position is in immediate proximity to the continuation of the well-marked east-to-west fault which has cut off the Barakars, &c., at the north-west corner of the Aurunga field. Were there a complete

section exposed, it is almost certain that it would give conclusive evidence of the existence of fracture and distortion in close proximity to the spring. Not improbably the hills at Joreesukhwa, a little further west, will, when examined, mark the line of fault. Reference to the map will, perhaps, render the above description more clear, and justify the probable correctness of the supposition.

Temperature.

The highest temperature of the water of the several outlets did not exceed 132° F. The amount of water poured forth, though not very copious, formed a steady stream. Sulphuretted hydrogen was emitted freely in bubbles, and its odour was apparent for some distance all around.

No peculiar development of vegetable life.

The springs being situated in the sandy bed of a running stream are not accompanied by any unusual development of vegetable life.

My attention was particularly directed to this point since I have, in the basin of the Mahanadi, met with some very interesting instances of considerable modification of the *Flora* in the vicinity of certain hot springs. I hope to obtain further data for the treatment of the subject hereafter.

It will be sufficient to indicate here how, in ancient geological periods, when hot springs were probably more abundant, there may have been local hot-house climates which would serve to explain such difficulties in connection with fossil floras as the occurrence of tropical or sub-tropical plants in the supposed glacial beds of Talchir age.

Hot spring at Thatha.

In the Hutar coal field in the vicinity of the village of Thatha (called Kokraha on the map), when examining the bed of the Thatha river, my attention was attracted by a strong sulphurous odour to a copious outburst of hot water, of the existence of which I had no previous intimation. Here the spring is distinctly connected with a marked disturbance of the Barakar beds, and the occurrence of a strong ridge of pseudomorphic quartz or fault rock, which is coincident with a line of fracture described on another page.

The highest temperature of this spring is 151°F. There is here a strong confervoid growth which forms felt-like masses in the pools warmed by the water, but I did not observe any modification of the herbaceous or arboreal vegetation.

Temperature.

Mr. Forbes in his Settlement Report says that he only knows of one hot spring in Palamow, which is at Mundul in tuppeh *Bari,* and of which the temperature is 180°F. As I understood from him that he had not himself visited the spot, I am inclined to believe that the locality given to him may have been Mundul, otherwise known as Jodah, which is however in tuppeh Durjag, and is not far from Thatha, and that therefore the present spring was meant. There is also a Mundul in tuppeh Bari, and hence perhaps the confusion arose. I think I should most probably have heard, when in that tuppeh, if there had been a distinct hot spring in Bari.

Hot springs at Tatapani.

In the Tatapani field in the Sirguja district west of the Kunhur, the hot springs have given a name to the village, and also to the tuppeh or parganah in which they occur.

They constitute, from their number and their copious outpourings, a very remarkable, and, in this part of India at least, a unique display. They are all arranged with one exception on, or in, the immediate vicinity of a strong ridge of pseudomorphic quartz and breccia, which evidently marks a line of fracture, since a little further west it cuts off and bounds the coal measures, while to the east in the Hutar field the faulted boundary is on exactly the same line of strike; and although in the former case the downthrow is on the north and in the latter on the south, the line of fracture along which the movement of subsidence of the coal measures took place, in both cases respectively, may be identical, but the continuity has not yet been fully established, as the intervening sections have not been examined. This agreement in strike, *vide* map, is probably something more than a mere coincidence, and accordingly attention is here directed to it with a view to future examination.

CHAPTER III.

MISCELLANEOUS.

SECTION 1.—INHABITANTS.

IN connection with the future development of the mineral resources of Palamow, it may be useful to make a few remarks on the leading characteristics of the population.

Palamow being, as Mr. Forbes has pointed out, a sort of border land, is inhabited by both Aryan and non-Aryan peoples. The former, as is usually the case, occupy the open and cultivated parts, which, though smaller in extent, support a larger number of individuals than the wilder regions inhabited by the latter. In the portion of Palamow under description, which includes a large part of these wilder regions, the non-Aryans largely prevail, and as these tribes would most likely furnish the most considerable proportion of the labour, it will be only necessary to describe them, the more particularly as the characters and capabilities of the various castes of Hindus do not, so far as I know, present any local or unusual peculiarities.

Non-Aryan tribes.

Both the principal families of Kols are represented—the Múndás by about a dozen different tribes among which the Chiros, Kherwars, Korewas, Paharias and Agurias are the most numerous; the Oraons by Oraons proper and Kol-lohars.

Múndás.

The Kherwars and Chiros appear to me to be both indolent and wanting in stamina. The villages of the former are generally excessively dirty, and their houses, notwithstanding the fact that building materials are generally abundant, are in a most miserable state of dilapidation. They are not likely to make good labourers; but possibly they might improve somewhat if the weight of indebtedness to the money lenders, which now depresses them, were removed from their shoulders.

Kherwars and Chiros.

Korewas and Paharias.

The Korewas and Paharias are wild and not very numerous tribes in Palamow, but are more abundant in Sirguja. They are not likely to be of much account as labourers.

Aguria iron-smelters.

The Agurias are chiefly iron-smelters, but some have taken to cultivation. Colonel Dalton refers them to the Múndá family, while the Kol-lohars are considered to be Oraons. The statement made by Mr. Justice Phear in a memorandum[a] on the iron of Karanpura, that the Agurias are a low caste of Aryans, therefore is probably incorrect. But there is no doubt that the Loharias proper, or workers in iron, of whom also there are representatives in Palamow, are Hindus. Occasionally, I believe, these latter smelt, as well as refine and work up iron.

All these artificers would be useful and could be easily trained to manipulate iron ores in the European fashion. But for general purposes the Oraons would furnish the best and most abundant labour.

Oraons.

In Palamow the Oraons are found in various parts; those in the more open tracts having lost many of their tribal characteristics. In Toree they appeared to me to be tolerably numerous. From other parts of Chutia Nagpur they could be attracted in large numbers if necessary. At present a steady current of them flows in the direction of Assam and Cachar; the only means of arresting which, and preventing depopulation of wide areas in Chutia Nagpur, will be to give them remunerative occupation nearer their homes.

SECTION 2.—ROADS AND CARRIAGE.

This section might almost be written in the words, *mutatis mutandis*, of Aldrovandius' famous chapter concerning the owls of Iceland.

Principal roads.

Of *pucka*-bridged roads there is not a single example in the whole area. The few roads that do exist are little better than mere fair-weather tracks. Of these the

[a] See Appendix F. to a paper read before the Bengal Social Science Association on the 24th July 1876.

principal are from Daltonganj to Ranchi, and from the same place to Dehree on the Sone. But few of the others are practicable for carts, and the remainder can only be used by pack cattle and elephants.

Except in Burkhol, I did not anywhere see any indigenous wheeled vehicles; these too were of the rudest description. Carts find their way along the two above-mentioned roads into Daltonganj; and recently timber has been drawn in carts from Sirguja over a track where carts never passed before. Judging from what I saw, I should say the average rate of progression of these carts was under three miles a day.

Export trade by pack cattle.

The export trade in grain is wholly carried on by means of pack bullocks, which are mostly of a small and weakly breed. The Oraons alone of all the tribes can be induced to carry banghies, the Kherwars and others carrying but half loads on their heads.

SECTION 3.—FORESTS AND WILD ANIMALS.

The forests of Palamow do not, I believe, contain much valuable timber at present, but the strict conservancy which has been initiated in parts of Bari, Durjag, Barasand, Sima, &c., promises a supply in the future.

Sal timber is by no means generally distributed. I often searched in vain for single examples in mixed jungle. In other places the soil does not seem to be well suited to its free development. However, it is possible that it may be larger and more plentiful in parts of the hills unvisited by me. Most excellent *sal* timber is now being cut in a neighbouring tract of Sirguja.

Teak, as is the case, to the best of my belief, throughout the Chutia Nagpur Division, does not occur.

The Forest Department, having been for several years in possession of the Palamow forests, will no doubt be able to state how far a trade in timber is likely to aid the traffic on the proposed line of branch railway. The ordinary jungle products, such as lac, kath or catechu, fibres, &c., need not be described here.

Wild animals.—Palamow has not a good reputation as a place for sport, but I have reason for believing that in certain limited areas wild animals are by no means scarce. Tigers and leopards were chiefly to be heard of in the vicinity of the Koel, where it crosses the Hutar field and thence westward to the Kunhur.

Mr. Forbes speaks of the chetah, or hunting leopard, having been at one time abundant, but the leopards seen by me, whether alive or dead, were all the so-called panther (*Felis pardus*). Bears are rare, as also are wolves. I saw but one pair of the latter near Latiahar. The sambhur and spotted deer are not common in the parts visited by me, but nilgai are abundant in certain tracts, as also are barking deer and the four-horned antelope. The gazelle is frequently seen in the west, and occurs close to Daltonganj. A pair were seen near Latiahar, longitude 84° 35′ E., which is, I believe, the most eastern locality where this animal has as yet been observed. *Gaur*, or bison so-called, are found on the ranges and pâts to the south. Occasionally they appear in the valleys as at Barkhol.

SECTION 4.—CULTIVATION.

The scarcity of tanks and *bunds*, and the unwillingness or inability of the people to provide irrigation for themselves—which extends, according to Mr. Forbes, to a disinclination even to repair temporary ruptures in bunds which have in some cases been made by the hired labour of a particular tribe called Nunias—account for the inferiority and uncertain yield of the crops and the generally impoverished state of the country.

Of the grain crops which are raised, no doubt a large proportion is exported, the people being too poor to use them themselves, even when they have not been wholly hypothecated, as they commonly are, to the mahajans on account of advances. The jungle products are the great stand-by, and furnish a means of subsistence to many thousands for several months of each year. The reservation of large tracts of forest has, however, curtailed the areas accessible to the people, and thus in bad seasons the relief to be obtained from these jungle products is less than it was formerly.

Jungle products.

Cotton.

Mr. Forbes seems to think that the cotton crop is the one most likely to flourish and yield a good return under proper cultivation. But for this to be successful a better class of seed should be imported.

The majority of cotton-bearing plants which I saw averaged under a foot in height. Not only is the variety grown a stunted miserable one, but it appears to be particularly subject to the attacks of insects; at least such was the case with the crops grown last season after the short rainfall. In at least 75 per cent. of the cotton fields seen by me, I noticed that the *bols* had not been collected, but had fallen to the ground where they were left to rot, the reason being, as I was informed, that the kernels had been eaten by grubs, and that it was therefore impossible to clear the fibre from the broken fragments of the seed shells in the rude machines (*chirkis*) used for that purpose.

Loss of last year's crops.

The damage done to the kharif crops by drought, to the rabi crops by rain coming too late and by heavy hoar-frosts, and finally to the crop of mhowa flowers by rain, while the collection of a most abundant harvest was going on, all contributed to make up during the last twelve months in Palamow a tale of loss and consequent suffering, without absolute famine, which it is most unpleasant to contemplate.

Crops how raised and exported.

In Mr. Forbes' report and the appendices will be found full information as to the principal crops grown and the amount of exports from which deductions may be drawn as to the probable amount of grain traffic. The immediate result of an increased prosperity among the people would, perhaps, be a diminution in the quantity of grain exported. But with the introduction of capital and improved systems of cultivation, this would be far more than recouped in a very few years.

SECTION 5.—CLIMATE.

The comparative healthiness of a district in which it is proposed to establish iron-works or other similar undertakings should be no mean

factor in the determination of the preliminaries of the project. So far as my personal experience goes, Palamow is the healthiest part of Chutia Nagpur. The amount of sickness in my camp was most conspicuously less than it has been in other parts of the division.

But the very different amount of sickness which I witnessed and participated in two successive seasons in Sirguja warns me from attempting to generalise on the personal experience of but one season in Palamow. The balance of testimony, however, seems to indicate that the healthiness of Palamow is above the average of similar hilly districts. The highland pâts might be advantageously used as local sanitaria.

Note.—It may, perhaps, be thought by some readers that the topics discussed in this miscellaneous chapter are hardly suitable to the pages of a geological report. But their connection with the question of the development of the mineral resources is not likely to be denied, and no other justification for their appearance here is, perhaps, necessary. There are many other subjects connected with the natural productions, the history and the antiquities and the ethnology which might be dwelt on at some length, but without the above justification. The introduction of all such subjects, therefore, is scrupulously omitted, and the information on the first-mentioned is conveyed in as few and as brief paragraphs as is consistent with a reasonable amount of clearness.

CHAPTER IV.

GENERAL GEOLOGY.

Formations Represented.

At one time it seemed probable that the termination of the series of coal fields in the Damuda valley would be found to be exactly coincident with marked changes in the characters of the Gondwana rock-groups, and that this would at once become apparent as new areas in the country farther west were brought under examination. Already in the Karanpura fields the central groups so well developed in the Raniganj field had been found to be diminished in thickness and modified in character. The result of the examination of the various coal-fields of Palamow has been to confirm the general truth of the view thus entertained, but the change has proved to be not quite so abrupt and is not coincident with the termination of the Damuda valley, but takes place farther west.

Correlation of rock groups not aided by fossils as yet.

Had it been abrupt, the difficulty in correlating the several groups would have been great, as the aid which might have been afforded by the presence of distinguishable fossils has been denied to us for the present. Fossil plants are not indeed wholly absent, as will appear on a future page, but they have not been available for purposes of determining the ages of the rocks in which they occur. The geological formations and sub-division of formations represented within the limits of the area herein described are as follows (in descending order) :—

		Superficial deposits.	
		Laterite.	
		Deccan trap.	
Gondwana system.	Upper	Mahadeva series.	
	Lower	Panchet group.	
		Lower "	Damuda series.
		Barakar "	
		Talchir "	
		Metamorphic series.	

Before proceeding to the detailed account of the above sedimentary formations under the headings of the different fields in which they occur, it will be well, with the aid of the accompanying small-scale map, to indicate generally the extent of their distribution so far as it is known throughout the whole area, and to point out the resemblances and relations which exist between the deposits of identical age in more or less widely-separated localities. But first it will be necessary to give a general sketch of the crystalline or metamorphic rocks which form the floor of the basins or troughs in which the more recent rocks have been deposited.

SECTION 1.—METAMORPHIC SERIES.

A considerable number of observations on these basal rocks have been accumulated during the season, in consequence of its having been necessary to make traverses in various directions, in order to examine deposits of iron ores at a distance from the coal fields, and also for the purpose of searching for outlying areas of sedimentary rocks. Although the observations made under these circumstances are therefore of a somewhat disconnected character, sufficient has been seen to show that the detailed examination of these rocks will not improbably throw much light on the origin of the leading structural features of the country.

Distribution of lithological varieties.

So far as is certainly known, the metamorphic rocks of this area belong to but one great series, but there are some marked features in the distribution of the several lithological varieties. In the west, massive granitic rocks with abundant veins of pegmatite and epidotic granite prevail. In association with them there is an enormous thickness of crystalline limestone which will presently be described. The economic importance of this rock will also secure for it some further notice in the proper section.

Hornblendic rocks.

Towards the centre of the area, west of Munkah, there is a complete change in the character of the rocks. Hornblendic gneisses are there the most common form met with. Many of these have a markedly trappean aspect, and are sometimes not

to be distinguished from trap. In association with these rocks occur all the principal deposits of magnetic iron ore.

Black mica granite.

Farther west, in the neighbourhood of Ramkunda, a black micaceous granite, which is occasionally syenitic, occurs over a considerable tract of country. To the south of this the granitic rocks are chiefly remarkable for including very fine veins of stilbite. Towards the Kunhur the hornblendic gneisses disappear, and among the granitic rocks a coarsely porphyritic variety becomes the most prominent form. Throughout the whole area schistose rocks are rare.

In the country south of our main area rise several lofty ranges of hills which are principally formed of metamorphic rocks, but on some of them deposits of sandstone, trap, or laterite occur, forming distinctly marked caps. The Gulgul and Neturhat pâts belong to this latter class and have bases of highly granitoid gneiss.

Fault rock at Pukree.

To the above general sketch of the distribution it will be well to add some further details. Approaching the Aurunga valley by the road from Balumath, a very distinct ridge of fault rock is met with crossing the road near Pukree and striking thence to west-south-west. A mile farther on, at Olherpât, there is a considerable exposure of limestone. This consists partly of highly calcareous gneiss and partly of vein-like lenticular masses of crystalline limestone. For about a mile and a quarter, or nearly up to the village of Deredag, the road crosses the outcrops of similar rocks, the strike being to about 35° east of north, with varying, but high, dips.

Limestone.

In the Chunhat stream the limestone is clearly seen to be cut off by the fault, whose presence was indicated by the already mentioned fault rock. Close to the village of Chunhat the water charged with lime from this source falls over a step in the gneiss, and the evaporation of the spray and drip, extended over a long period of time, has resulted in the

formation of a very considerable bank of calcareous tuff which is well known to the people[a], though the limestone rock, as such, is not.

Calcareous tuff.

On the low plateau ground to the south of this position the limestones, flung westward by the fault, reappear and are seemingly richer and purer than they are at Olherpât. The following is the result of an examination of a sample from this southern locality by Mr. Mallet:—

Carbonate of lime	91·9
„ magnesia	·2
Oxide of iron and alumina	·7
Insoluble	7·2
	100·0

The small proportion of carbonate of magnesia and the purity in other respects indicate a high value for this limestone as a flux for iron-smelting.

The limestones are covered up on the west by Barakar grits and conglomerates, upon which too, in the neighbourhood of a stream, a tuffaceous deposit is in process of formation. The continuation of the fault is marked near the village of Koorean by a ridge of fault rock which is surrounded on all sides by Barakar beds, those on the north dipping away at high angles. This is to be attributed rather to subsidence along the old line of fracture than to the original fault, which, in all probability, operated before the deposition of the Barakars.

Continuation of fault.

Had it taken place subsequently, its effects, considering the fling it has certainly given to the limestones, should be distinctly traceable in the distortion of the ironstones and carbonaceous shales beyond Lejang, but no such distortion is to be seen.

Along the eastern margin of the field the bounding rocks are chiefly granitic gneisses with veins of quartz and pegmatite. Inside the margin a small inlier of these rocks is exposed one mile north-west of

[a] This is shewn by the name of the village, which is derived from *chuna* (lime).

the village of Seruk. To the north of the field at Balu-naggar there are several hills connected with the higher regions bordering the valley, which are formed chiefly of thin-bedded hornblendic gneisses, with veins of coarsely crystalline pink granite and pegmatite, and capped by Barakar pebble conglomerates, as will be described on a future page. In the valley of the Tataka, to the west of this, the rocks consist chiefly of gneiss with pegmatite and epidote veins, but hornblendic and granitic rocks also occur. The general strike of these rocks is the same as that of the bounding face of the plateau and of the subordinate ranges, being about east-north-east to west-south-west.

Sandstone-like gneiss.

A very peculiar form of gneiss, which I at first mistook for indurated Barakar sandstone, occurs in that portion of the Sukri which lies to the north-west of Toobed. Foliation is obscure, and the face of the rock shews lenticular masses and strings of coarsely granular structure, which closely simulate the irregular texture of certain Barakar sandstones.

Pot-holes.

These rocks are cut into a deep gorge by the Sukri and are in places eroded into pot holes of considerable dimensions. The rocks which surround the remainder of the western extension of the Aurunga field consist mainly of varieties of granitic and hornblendic gneiss, about which there is nothing of importance to be recorded.

Calcareous gneiss.

On the southern side of the field the metamorphic rocks have a generally similar character. It is noteworthy that in the Aurunga river section, a short distance north of the Daltonganj and Ranchi road near the village of Bhoosor, the gneisses are somewhat calcareous, and that they are on about the position of the south-west continuation of the direction of strike of the above-described limestones of Chunhut.

Inliers.

Besides the inlier already mentioned north-west of Seruk, there are several other localities where metamorphic rocks occur inside the boundary. In the Sukri section

east of Mooroop there is a small exposure of granitic gneiss within the limits of the Barakars.

Near the villages of Bindee and Ledupali gneiss occupies two small areas within the boundary of the Talchir rocks. Reference to the map will shew the position and relative importance of all these.

Hornblendic gneiss.

In the valley of the Aurunga to the north-west of the Aurunga field the metamorphic rocks consist chiefly of hornblendic gneisses, and in some cases, as in the neighbourhood of Kedh and Bansdeeh, of hornblendic rocks with a cannon ball structure which may be really intrusive diorite so far as anything is certainly known to the contrary. In association with these rocks occur all the principal deposits of magnetite as at Lunkah, Rajhera, &c. These will be fully described in the economic chapter.

Limestones near Satbarwah.

In the Maila river section, half a mile east of Satbarwah, there is an exposure of a considerable thickness of limestone, and calcareous gneisses. They do not appear to be nearly so pure or clean as those in the Toree parganah above described. A fair average sample yielded to Mr. Mallet the following percentage composition:—

Carbonate of lime	60·8
" magnesia	16·0
Alumina and oxide of iron	5·0
Insoluble	18·2
	100·0

This would be a very indifferent flux for iron-smelting, but it is possible some portions may prove to be of better quality.

The hilly ground on both sides of the Koel above its junction with the Aurunga, and thence, up to and beyond Daltonganj, consists of similar rocks, with which granitic varieties are occasionally interpolated. This region has not yet been thoroughly explored; but so far as is at present known, the only sedimentary rocks found there occur as a cap of arkose grit, which forms the plateau of the Chongah hill station.

Labradorite with calc-spar.

On the hill east of the village of Kokaroh there is a vein of white rock consisting partly of calc-spar and partly of a mineral which has been analysed by Mr. Mallet, who regards it as an abnormal form of labradorite.[a]

Passing now to the description of the rocks in the area surrounding the Hutar field, it is found that they present no general characters which would serve to distinguish them from those in the neighbourhood of the Aurunga field, but there are several points about them deserving of notice. At the north-east end of the field they are traversed by clearly defined trap dykes, no similar intrusions having been met with elsewhere.

Trap dykes.

On the south a lofty range which runs east and west, and is continuous with the one forming the southern limit of the Aurunga field, is formed of granitic gneiss, with quartz and granite veins of ordinary character. This ridge is very possibly connected with a line of faulted upheaval.

Neighbourhood of Ramkunda.

North-west of the field in the region surrounding Ramkunda, the metamorphic rocks are much decomposed, and there are wide tracts of raviny, unreclaimed land, covered by sál and bush jungle. The map well illustrates the character of the network of streamlets and ravines abounding in that neighbourhood. Where rock has been conserved, it mostly appears in the shape of bosses and tors of a black syenite-looking rock, some of which is indeed lithologically true syenite, but more commonly the colouring mineral is black mica and not hornblende.

Stilbite.

In this region, south of the village of Manjuri and at the mouth of the stream which, rising in the Bijka peak, joins the Atee river, there occur several veins of stilbite. This mineral, though well known to occur in metamorphic as well as volcanic rocks, has been but rarely met with in India in this association. I am unaware of the existence of any record of its having been found elsewhere in this country in equal profusion and beauty.

[a] It is partially decomposable by HCl. The filtrate contains alumina and lime. It does not gelatinize with acid. It contains no water. Hardness 6·5.

Three distinct veins were observed: the principal one occurs about 80 yards in from the mouth of the stream. It is from half an inch to ten inches wide, with a vertical underlie, and strike of about west-20°-north. Though for the most part the vein lies parallel to the planes of foliation of the pink porphyritic gneiss which encloses it, it does not invariably do so. The mineral has a laminated, somewhat hackly structure, and is of a bright salmon-coloured hue with a pearly lustre. Associated with it, there are plates of quartz pseudo-morphic after micaceous iron.

A second vein occurs close to the mouth of the stream. It is in places one foot wide, and the combination in it of the stilbite with the pseudo-morphic quartz produces a very beautiful structure.

A third smaller vein was noted in the bed of the Atee. Very possibly there may be others also.

Veins of pink pegmatite and epidote occur in some abundance also in the vicinity of the stilbite.

Supahi river sections.

West of Hutar field the sections in the Supahi exhibit a considerable variety of the ordinary forms of gneiss with veins of granite, pegmatite and quartz. Hornblendic rocks are there more rarely represented, but are by no means wholly absent. Towards the valley of the Kunhur coarse porphyritic gneis comes in abundantly often forming considerable ridges.

The pâts.

Traverses made southwards from the region above described to the Neturhat and Gulgul *pâts* or plateaux did not reveal the presence of any metamorphic rocks meriting particular or special notice. It may be stated, however, that the face of Neturhat on the north is principally formed of a massive felspathic granite, in which foliation is either very obscure or wholly non-existent.

Sub-metamorphic series absent.

Rocks referable to the sub-metamorphic series are not represented in this area, but only a few miles off to the south and south-west they are found in the neighbourhood of the Bisrampur coal field in the district of Sirguja.

SECTION 2.—TALCHIR GROUP.

GONDWANA SYSTEM:

The following table indicates the geographical distribution of the Gondwana rock groups in Palamow and the neighbouring portions of the adjoining districts:—

Table showing the distribution of the Gondwana rock groups in the coal fields of Palamow and adjoining areas.

HAZARIBAGH.*			PALAMOW.			SIRGUJA.	
Itkuri.	Chope.	Karanpura.	Aurunga.	Hutar.	Daltongunj.	Tatapani.	Bisrampur.
...	...	Mahadeva ...	Mahadeva ...	Mahadeva	...	Mahadeva	Mahadeva.
...	...	Panchet ...	Panchet.	......	......	......	......
...	...	Raniganj ...	Raniganj.	......	......	......	......
Barakar ...	Barakar ...	Barakar ...	Barakar ...	Barakar ...	Barakar ...	Barakar ...	Barakar.
Talchir ...	Talchir ...	Talchir ...	Talchir ...	Talchir ...	Talchir ...	Talchir ...	Talchir.

Besides the above there are several isolated areas both in Hazaribagh and Palamow where the Talchir group only is represented.

The Talchir rocks have recently, on account of the characters of their fossil contents, been degraded from their position as a series readily separable from all rocks of the Damuda series to that of a group under the widely-spreading embrace of the Gondwana system. But the very latest examination of their physical relations tends only to confirm the propriety of the earlier classification.

It is believed from the characters of the fossils that the coal measures of Karharbari are really of this age in spite of lithological resemblance to Barakars. On this particular case I offer at present no opinion, but can only say that in the many fields which I have examined the

* Only the coal fields of the Hazaribagh district which are the nearest to Palamow are included here.

Talchirs appear to me to be separated by a greater hiatus from the overlying coal measures than is implied by speaking of them respectively as being consecutive groups of the same series.[a]

The Talchir rocks in our area, though nowhere *exposed* over so extensive a tract as they occupy in the Daltonganj field, are still, in all probability, widely spread under the newer deposits.

Their presence is indicated by narrow marginal strips at separated intervals along the boundaries of the Aurunga field, and in more steadily continuous exposures round the limits of the coal measures of the Hutar field. They occur also on the eastern margins of the Tatapani and Bisrampur fields. Several detached outliers in the vicinity of the Aurunga field are partly, or altogether, made up of rocks of this age, and at Satbarwah, in the bed of the Maila (or Mylee) river, they occupy an area of about three square miles, being unaccompanied there by any more recent deposits.

Talchirs at Satbarwah.

As this Satbarwah area is about centrically situated with reference to the three coal fields of Daltonganj, Hutar and Aurunga, it can scarcely be regarded as pertaining more to one than to another. The rocks there occurring may, therefore, most fittingly be described in this place. The fact of their existence has already been noted by Mr. Hughes in his report on the Daltonganj field[b] and by Mr. Forbes in his settlement report.

The area occupied by these beds extends as an irregular strip for nearly five miles along the bed of the Maila, with an average width of about two-thirds of a mile. East of the village of Bari the boundary is concealed by alluvium, and it may be that the Talchir rocks extend for some distance under the cultivated plain in that neighbourhood.

The ordinary varieties of sandstones, shales and boulder conglomerates represent the group in this area; but it is noteworthy that in some of the last-mentioned beds, in addition to rounded boulders of metamor-

[a] This question has many points in common with the difficult one as to the limits of the terms 'genus' and 'species.'

[b] Memoirs, G. S. I., vol. VIII, page 22.

phic rocks, large-sized angular fragments of vein-granite and gneiss occur in some abundance.

Thickness.

In the Daltonganj field Mr. Hughes estimates the thickness of the Talchirs at 500 feet. In the area under description they probably do not exceed a total of 300 feet.

Abnormal rocks.

The members of this group, within the limits of the Aurunga and Hutar fields, possess lithological characters which, as a general rule, may be described as being normal. There are some exceptions to this rule, however, which merit particular notice. In the Aurunga field near Latiahar there are some sandy and fibrous shales, with papery carbonaceous layers, which for reasons given further on I refer to this age. In the Hutar field in some instances there is found to be in the boulder bed a preponderance of red (Vindhyan) quartzite boulders over those derived from the neighbouring metamorphic rocks.

Besides the areas herein described it is not improbable that other detached patches of Talchirs may be found in the hilly broken ground surrounding the coal fields.

SECTION 3.—BARAKAR GROUP.

The lithological characters of the rocks of this group vary very much in the different coal fields of Palamow.

In the Daltonganj field Mr. Hughes found[a] that the typical Barakar sandstone of the eastern fields is replaced by "a false-bedded rock with fine and coarse layers of sand deposited often at an angle of 50° with the plane of the bedding." It is friable, earthy and slightly calcareous and consequently rather resembles a common form of sandstone in the Raniganj group than it does any normal Barakar form previously met with.

Lithological characters of Aurunga Barakars.

In the Aurunga field the rocks of this group may, in general terms, be described as being normal, perhaps even more so than they are in the Karanpura field. The ordi-

[a] Memoirs, G. S. I., vol. VIII, page 333.

nary forms of sandstone grits and conglomerates all occur, and huge seams, consisting largely of carbonaceous shale, are found at various horizons and with most irregular lateral extension. As will be amply exemplified in the detailed sections which are given below, the irregularity in the deposition of the various Barakar beds was extreme. Internal overlap exists on a large scale being very clearly shewn in certain closely adjacent sections, where beds are seen to thin out or expand, as the case may be, with extraordinary rapidity. The bottom beds are usually conglomerates, with small rounded pebbles of white quartz. Occasionally, however, these are replaced by what would be more properly denominated as *breccias*, the fragments of quartz being sharply angular and quite unworn, in this respect resembling some of the coal-measure conglomerates of the Karharbari field. In the eastern parts of the field these lowest beds are often covered by white and pinkish, somewhat clunchy, clays. Occasionally, too, there are dark-red clays at about the same horizon, but sometimes these last occur at the very base, in which cases they might very probably be taken as belonging to the Talchir group, from which however they must, I think, be separated.

Internal overlap.

Above this lower zone comes one of variable thickness, consisting of sandstones, carbonaceous shales and ironstones, which extends up to the base of the Raniganj group. In the sandstones next adjacent to the conglomerates concretionary masses of brown or red hæmatites occur in considerable abundance. These are covered by an irregular sequence of carbonaceous shales (with coal), ironstones and sandstones, which in some instances, as at Toobed on the north, and in some of the sections of the Aurunga and Ghugree on the south, have completely overlapped both the iron-bearing sandstones and the conglomerates of the lower zone, and rest directly and naturally on the metamorphic rocks.

Thinning out to west.

In the neighbourhood of Latiahar this upper zone has a very much diminished thickness, and west of the Aurunga has wholly disappeared, for we find there that the Mahadevas rest directly on the lower conglomerates. How far this

is attributable to original limitation of the area of deposit, how far to denudation, is uncertain; but that some denudation took place is probable, though there are no very clear sections showing unconformable superposition.

Thickness.

The maximum thickness of Barakar beds in the Aurunga field is about 1,500 feet.

Coal inferior.

As a coal-bearing group the rocks of this field take but low rank; for although the quantity of coaly matter is great, the quality is markedly inferior to that of the coal in the other fields.

Disturbance.

Although the Barakar beds in certain tracts throughout the field do not show signs of much disturbance, great local tilting is of common occurrence. This is particularly found to be the case along the *natural* boundaries, and appears to be attributable to lateral thrust and compression, produced in connection with several considerable main lines of fault.

In many of the sections a vertical contact between the bottom beds of the Barakars and the metamorphic rocks has been thus established.

Lithological characters of Barakars in Hutar field.

In the Hutar field, although its position is so closely adjacent to that of Aurunga, the coal measures present many points of striking contrast to those just described. In the east of the field the Talchirs are overlaid by sandstones and conglomerates, which form hills and plateaux having a stronger structural resemblance to those formed of Mahadevas than have the hillocks and ridges which usually characterise areas where Barakar rocks are found.

In the Dauri river section, and thence westwards to the extreme limits of the field, a basal zone of sandstones and conglomerates with coal seams first appears,—no trace of coal being seen in the scarps of the hills and sections which are passed before that river is reached.

To this basal zone the whole of the coal is confined, and not only is there this contrast with the state of things just described, but the coal seams are themselves of a completely different character. Instead of the thick irregular seams, which consist largely of carbonaceous shales as above described, we here meet with seams which are generally thin, sometimes lenticular, and consisting of a more compact and uniform material which is sometimes a high class fuel. These seams are parted from each other by massive beds of sandstone, the whole being contained in a zone, very possibly not exceeding 200 feet in thickness, which exists as a margin, internal to the Talchirs, all round the western portion of the field, except at those points where it has been cut off by faults.

Coal zone.

On the right or eastern side of the Koel river the high ground is formed of sandstone grits and conglomerates, which, as has been above stated, overlap on to the Talchirs at the eastern end of the area. At one time I was inclined to suppose that some ferruginous beds which occur near and at the top of the rocks forming these highlands might possibly belong to the Mahadeva series, but I was afterwards compelled to class them all as Barakars.

The thickness of the group as now existing in this portion of the field is probably under 600 feet. West of the Koel a curious change takes place, the upper overlapping zone of sandstones and conglomerates thins out and no longer forms hills and plateaux. In the extreme west it is represented by but a narrow zone of sandstones and conglomerates which overlies the coal-bearing zone, and is overlaid by a considerable but varying thickness of beds forming a synclinal basin, and of which the determination of the age and affinities has been a considerable source of doubt and difficulty. Though in places somewhat resembling true Barakars, their more constant lithological characters may be described as being unique. They consist of coarse grits and conglomerates, the latter containing not unfrequently fragments of metamorphic rocks, and not being composed

Thickness west of Koel.

Top beds west of Koel abnormal.

exclusively of rounded or angular white quartz pebbles, as is commonly the case with normal Barakars. Associated with them there are green, somewhat clunchy, clays, and occasionally soft yellowish sandstones. This group is overlaid by Mahadevas, which are precisely similar in lithological and structural characters to the rocks of the same age in the Aurunga and Karanpura fields. How far the superposition by these Mahadevas is strictly conformable, it is difficult to say; but that the thickness overlaid varies very considerably in different places is sufficiently obvious, as will be seen by reference to the map.

From their position the rocks of this zone might be taken to represent the Raniganj group, but the lithological characters of the grits and conglomerates are a bar in the way of this supposition, normal Raniganj rocks being strongly characterised by the fineness and uniformity of their texture. To the grits which occasionally occur in the Panchets (Lower Panchets of old classification), they present a certain but not sufficiently close resemblance for satisfactory correlation.

Correlation.

The alternative left is to regard them as a local sub-group of Barakars with special characters. In favour of the adoption of this view, there is the fact that irregularities produced by thinning out being excepted, they rest with perfect uniformity on the beds of the lower zone, and that a few cases were met with where green clunchy beds appeared to occupy a position within the limits of the lower zone, thus preceding, and as it were anticipating, the coming more general change.

Tatapani field.

In the Tatapani field west of the Kunhur, so far as my brief examination of it enabled me to form an opinion, similar rocks occupy the position of the intermediate sandstone and conglomerate zone which has there died out, and rest directly on a thin bottom zone of sandstones, carbonaceous shales and coal.

On the map the limits of this sub-group in that portion of the Hutar field which lies west of the Koel is indicated by a dotted line. I have not thought it to be advisable to distinguish it by a separate colour at present.

Including this sub-group with the lower rocks of undoubted Barakar age, there is a total maximum continuous thickness of 2,750 feet in Hutar field, the line of section being measured in the valley of the Supahi from Toleh or Tiharo to the foot of the Doothoo Hills.

SECTION 4.—RANIGANJ GROUP.

Since within our area representatives of this group are alone found in the Aurunga field, it will be better, as avoiding unnecessary reiteration, to refer to section 3 of Chapter V for a description of them. The maximum thickness I estimate at from 900 feet to 1,000.

SECTION 5.—PANCHET GROUP.

The above remark applies to the rocks of this group also. An account of the Aurunga field Panchets will be found in section 4 of Chapter V. The maximum thickness does not exceed 700 feet and is possibly less.

SECTION 6.—MAHADEVA SERIES.

In the table given on page 38 it will be seen that this series is represented in all the fields from Karanpura to Tatapani which lie on the same line of strike. Not only is the correlation fully established by the identity of lithological characters, but the physical features of the successive plateaux or groups of hills occur with an extraordinary repetition of minutiæ. The conclusion from these facts, that these now detached areas are the remnant of a once continuous deposit seems to be unavoidable.

Deposits of the several fields once continuous.

The lithological characters which are thus constant for the distance mentioned are somewhat different from those of the deposits in the more eastern fields of Bokaroh and Raniganj. Notable in this respect is the scarcity of conglomerates and the absence of that form to which the name of pudding stone might be applied. On the other hand, there is a very considerable resemblance between these rocks both structurally and lithologically, and those of the Hingir field, whose fossil

Lithological characters.

Resemblance to Hingir Kamthis.

contents have determined their age as belonging to the Kamthi-Raniganj groups. This lithological resemblance is even strikingly apparent in the hand specimens placed side by side in the Museum. But for the existence of representatives of the Raniganj and Panchet groups in the Aurunga field and the obvious identity of these highest rocks with those in the Karanpura field, I should have been at first inclined to regard these rocks as being identical with the Hingir rocks. The reflection suggested is that either the Hingir rocks are separable into two groups, or that they indicate a coalescence or blending of the characteristics of two groups which in this area are separated by a distinct interval. The geological history of other countries furnishes us with cases parallel to the latter. The fact indicates the difficulties which will be experienced in relegating these often unfossiliferous rocks which occur in the wide region to the west and south-west to their proper positions in the geological sequence.

Elevation of top beds of Mahadevas.

Along this central line of distribution there can be little doubt that the general surface of the Mahadevas before being denuded stood at a pretty continuous and equable level of rather more than 2,000 feet, *i.e.*, at the same level as that of the bounding plateaux.

Age of hill capping sandstones unascertained.

The correlation of certain sandstones which occur as caps on some of the hill tops and ridges in the neighbourhood of the fields, more particularly on those south of the Aurunga, has not yet been finally accomplished, and it is to be regretted that there has as yet been no time for doing so. *Primâ facie*, it might justly be anticipated that, wherever in the vicinity of the coal fields sandstones occur at elevations of, and over 2,000 feet, they would prove to belong to the Mahadeva series. But the result of examination hitherto has been to demonstrate that, while the Damudas are represented by widely-separated deposits which occur at various elevations[a], the Mahadevas are restricted within very narrow

[a] *e. g.* in the Daltonganj, Chope, Itkuri and Karharbari fields.

and easily defined north and south limits. Rocks which it is believed belong to the same age do, indeed, occur in the Rajmahal hills and in the Bisrampur field in Sirguja, but these are localities so far removed from the tract of country under consideration that they may for the moment be disregarded. The fact then to be accounted for is the occurrence of these Mahadevas along a zone of country 240 miles long and from 3 to 12 miles wide, this maximum width being attained in but one place in the Karanpura field, which occupies about the centre of the whole length. Otherwise, the distribution may be indicated by saying that, excepting the areas in the Raniganj field, which are slightly to the south, it is confined within the 23° 40′ and 23° 50′ parallels of north latitude.

Limits of zone of distribution.

We have evidence, afforded by the present varied elevations of the coal measure deposits, and the frequent recurrence of great lines of east and west faulting in the Damuda valley and more western coal fields, that great disruption of the originally much more extensive and continuous deposits took place;[a] and that while the broken and disturbed areas raised to the higher elevation have been much denuded, the principal coal fields have been preserved in consequence of their being protected in a trough produced perhaps by a fold in conjunction with the faulting.

Cause of the limitation.

In this trough or valley a huge sluggish river, with little power for excavating, may have flowed and gradually deposited the sand and gravel which has formed the Mahadeva rocks.

The past history of the Panchet group has not been alluded to, but it seems probable that it is the same as that of the older groups, though both it and the Raniganj and Ironstone Shale group have this in common with the Mahadevas, that their distribution is restricted to a definite zone. There is, however, a

Past history of the Panchets.

[a] On a first glance at the map the clear definition of the valleys in which the Aurunga and Hutar fields respectively lie suggests that these were the original limits of deposition, but examination rather tends in the direction of showing that these bounding highlands are due to subsequent upheaval.

much more marked unconformity between the Mahadevas and the underlying Panchets than there is between the other groups respectively.

Scarcity of collateral evidence of disturbance.

The absence, in the eastern fields, of clearly marked unconformable junctions showing disturbance is no doubt a difficulty in connection with this theory, as some evidence of the kind might reasonably be expected; but if it be remembered that the disturbance need not have been very marked along the central axis of the subsided rocks[a], and that the scour of the supposed river could not be very great, as the average gradient throughout the 240 miles can scarcely have exceeded three feet per mile[b], the difficulty is considerably lessened.

Possible denudation of groups to west of Aurunga field.

Moreover, it may be that the absence of the normal sequence of beds between the Barakars and Mahadevas in the west may really be due to denudation. Thus to the west of Latiahar in the Aurunga field, and in the Hutar and Tatapani fields, the Mahadevas rest directly on the Barakars without the intervention of representatives of the groups found to the east.

Thickness.

The maximum thickness of these beds is probably not less than 800 feet, and may be nearer to 1,000. In the detailed accounts below I give measurements. With Mr. Hughes' estimate of the thickness of these rocks in the Karanpura field I cannot agree. "Three or, perhaps, two hundred feet," he writes, "would probably be its maximum development." But in some of the scarps wholly formed of these rocks in the Karanpura field, a thickness of 500 feet is frequently exposed, and in the Maudih hill the total thickness must be several hundred feet more.

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[a] On the *margins* of the fields in those cases where there are no main bounding faults, there are often evidences in the tilted beds of great lateral crushing and pressure.

[b] The Balumath watershed (*vide* p. 13) was very possibly formed after the deposition of the Mahadevas. If it existed before, the beds in the Karanpura and Aurunga fields, although the scarps are so similar, could not have been continuous.

SECTION 7.—DECCAN TRAP AND LATERITE.

In the localities where Deccan trap and laterite occur their relations are so intimate that it will be most convenient to describe them together. Neither are found within the limits of the coal fields. Indeed, low-level laterite seems to be wholly absent in this area,* and the only trap which has as yet been met with occurs in the form of dykes which traverse the metamorphics and in places the Talchirs along the northern margin of the Hutar field, and belongs very possibly to an earlier period than the Deccan trap, but which must, however, have been subsequent to the Talchir period.

Low-level laterite absent.

So far then as our present knowledge goes, these rocks are confined to the highest elevations on the south of the subdivision and the neighbouring tracts of Lohardugga proper. It is possible that they may hereafter be found at lower elevations; but so far as they have hitherto been examined, the base of the trap does not occur in this region below elevations of about 3,000 feet above the sea. The *páts*, or plateaux which have been visited by members of the Geological Survey so far are known by the following names: Neturhat, 3,356 feet; Lamtipât, 3,777 feet; Gulgulpât, 3,823 feet, Mailampât, 4,024.

Occur only at high elevations.

Neturhat.—The ascent of this plateau was made on the north side from the village of Pindra, which is situated south of Simah. The base is formed of a massive felspathic granite, which is exposed to within about 420 feet of the top. Laterite, fallen and to some extent reconsolidated, then appears, but it is doubtful whether it occurs there in original contact with the gneiss, since boulders of trap were found about 240 feet higher up or within 180 feet from the summit, after which laterite only was seen. No trap was actually observed *in situ* near this line of ascent. Possibly

Section.

* Detailed examination of the northern portion of the district, not yet visited, may perhaps reveal some.

near some of the other routes there may be clearer sections of the scarped sides of the plateau.

Lithological character of laterite.

The laterite varies much in character. Sometimes it is pisolitic and argillaceous, containing but a small quantity of iron. Occasionally, it is cellular with a larger percentage of ferruginous matter, passing thence into a remarkably rich brown ore (limonite),[a] which contains 45·5 per cent. of iron, and is smelted by the Neturhat Aguriahs.

Summit of plateau.

The Neturhat plateau is about 4 miles long by 2½ broad, but this is likely to give an exaggerated idea of its area, which does not exceed about 7 square miles. The central southern portion forms a basin traversed by a perennial stream, which runs from south to north. The laterite within this basin is covered by about a foot or so of soil, and the locality has already attracted two tea companies, as has already been mentioned.

Lamtipât is in close proximity to the Gulgulpât about to be described. The thicknesses of the trap and laterite respectively have not yet been ascertained, but both are believed to occur there.

Sections.

Gulgulpât.—On this hill, which is a long ridge, capped at its centre by a steep-sided mass of laterite and trap, gneiss was found exposed up to a point about 260 feet below the summit, or in other words at an elevation of 3,563 feet above the sea. Fallen laterite then conceals the section; but trap boulders were noted at least 90 feet higher, though no trap was seen *in situ*.

The crowning layer of laterite is, perhaps, 60 feet thick and is much split and crevassed. The huge blocks so separated have, in some cases, fallen away from the mass and present a strange appearance, which is in some cases intensified by the creepers and luxuriant jungle which in part conceal their Titanic dimensions. Much of the laterite is pisolitic and similar in character to that of Neturhat, but I did not

[a] This I believe to be the ore called *dherbur* by the natives.

meet with any ore of iron equal in quality to the Neturhat stone. So far as I know, none is worked. The only inhabitants on the slopes are semi-wild Korewahs, whose very extensive hill clearances have laid low considerable tracts of forests.

Mailampât.—This plateau, which has a considerable extent of flat ground on the top, has not as yet had its trap-laterite cap measured. Other well-known plateaux of considerable extent, but situated beyond our present limits, are those known as Jamira and Main pâts.

Laterite a natural water reservoir.

The important part played by these laterite caps as reservoirs for water from which a perennial supply finds its way into the valleys cannot be over-estimated. On Neturhat, as stated above, the quantity is sufficient to form a running stream, which traverses the centre of the basin. On Gulgulpât there is a spring coincident with the boulders of trap abovementioned, or 170 feet below the summit. It is not improbable that it marks the line of junction between the permeable laterite and impermeable trap.

The occurrence of water on these pâts will give them great value as sites for tea plantations when the country is opened up and becomes more accessible.

SECTION 8.—SUPERFICIAL DEPOSITS.

On the accompanying maps the positions of the principal deposits of alluvial character, which conceal the underlying rocks, have been indicated in writing. The thickness of these deposits in the basin of the Koel is inconsiderable, but in the vicinity of the Kunhur there are deposits of some magnitude, both as regards their vertical and horizontal dimensions.

Kunkur.

Kunkur occurs abundantly in a few localities, which are principally, though not exclusively, on, or in close proximity to, rocks of Talchir age. But the amount available cannot be compared in abundance to the extraordinary rich deposits

which occur in the neighbourhood of the Daltonganj field, and which have been remarked on by Mr. Hughes.

Calcareous tuff.

The occurrence of calcareous tuff at Chunhut, on the east of the Aurunga field, has already been alluded to when describing the crystalline limestones which have supplied the material of which it is formed. A similar deposit is found in the river Mungurdaha at the foot of a waterfall near Kokaroh. Limestones were also found in that neighbourhood.

Perched tabular blocks.

The principal, or at least the most noteworthy, deposit of diluvial origin in our area is a red sandy clay, which is directly derived from the Mahadeva sandstones, and forms a belt of unculturable land, much intersected by ravines and surrounding the base of the Mahadeva hills. Fallen tabular masses of the ferruginous sandstone occur sometimes enveloped in this deposit; but more commonly, the result of erosion has been to isolate these masses and leave them perched on columns of stiff clay which often stand out at heights of ten feet or more above the general level of the country. The tabular blocks are frequently from 200 to 300 cubic feet in solid content, and when seen thus perched up above the low brush jungle present a very striking appearance.

SECTION 9.—FAULTS.

The great lines of fracture in our area, of which the faulted junctions afford evidence, are by their compass-bearings resolvable into three groups or systems. This arrangement, as will be seen, does not necessarily imply synchronism. So classified, they would stand as follows :—

1. East to west faults.
2. North of east to south of west faults.
3. North of west to south of east faults.

1. East and west system.

Of east and west faults three have been clearly discriminated by their effects in the Aurunga field, and two in the Hutar field. The effect of the southern pair in the Aurunga field has been to lower the Mahadevas to the level of the Barákars, cutting out all but small remnants of the two.

intermediate groups (Raniganj and Panchet). They have in conjunction with the great north-west south-east fault facilitated the upheaval of the wedge-shaped areas of metamorphic rocks which give to the field, as mapped, an appearance which, at first sight, might be thought to be due to a huge fling and distortion of the field by the agency of the north-west south-east fault alone. Owing to the fact that where the more southern, east and west fault intercepts the north-west south-east one, and similarly where the more northern of the pair intercepts the Latiahar and Putkee fault, no lateral displacement in either case is discernible, the question of relative ages becomes one of some difficulty. The balance of probability, however, seems in favor of the north-west to south-east fracture having taken place first, and that the rocks were simply vertically upheaved in the angles when the east and west faulting took place. The other east-west fault of the Aurunga field is that which forms a portion of the northern boundary where it cuts off several patches of Barakars and is connected with the hot spring at Jarum.

Relative ages.

In the Hutar field one east and west fault has cut off the Barakars at Morwaie, from whence westwards up to the Koel its course is indicated by fault rock and the hot spring at Thatha. West of the Koel its existence is somewhat doubtful, but its line of strike coincides with the base of the scarp of the Doothoo hills, and its existence there would help to account for a diminished thickness of the Barakars south, as compared with those north of the hills.

Hutar field faults.

The other east and west fault of this field is well marked near Binda, where it has cut off the small patch of Talchirs and Barakars. Apparently it is older than the neighbouring fault of the north of west to south of east system.

2. North of east to south of west system.

The first example of this system to be mentioned is the one which has flung the limestones described in section 1 of this chapter. Its course from Pukree to Korean strikes 15° north of east to 15° south of west.

I have already given my reasons for believing that the fracture took place before the deposition of the Barakar rocks.

The next example of this system runs between Putkee and Antekhita, forming the boundary at the extreme north-west prolongation of the field. The fractured junctions between the Barakars and gneiss in the Aurunga section clearly indicate the faulted character of this boundary. The strike is 20° north of east to 20° south of west.

The last representative of this system which has yet been proved forms the north-west boundary of the Hutar field, and is, it is believed, continuous with the line of fracture marked by fault rock, wherefrom the Tatapani hot springs take their rise. Where it forms the boundary of the field its faulted character is clearly indicated by the fractured junctions and cut-off patches in a series of cross-sections which are yielded by streams; its strike falls from 25° to 21°, north of east and south of west. There is nothing to indicate its relative age.

3. North of west to south of east system.

The first example of this system is the already described fault which bisects the Aurunga field. Its strike between Obur and Rukhant is from 47° north of west to 47° south of east. At Obur it is deflected about 17°, so that the direction between Jarum and Obur is from 30° north of west to 30° east of south.

The next of this system is the one which runs from Putkee to Latiahar; at several points it touches the bends of the Aurunga tangentially, and its faulted character is clearly apparent; its strike is 27° to 22°, north of west and south of east.

The last fault of this system is the well-marked one which forms the terminal western boundary of the Hutar field. Its strike is unusual, being 60° north of west and south of east. Properly speaking, perhaps, it ought to be classed by itself. From what I have seen of the metamorphic rocks I fully anticipate that their detailed examination will result in the discovery of other lines of fracture, having strikes referable to the above systems.

CHAPTER V.

AURUNGA COAL FIELD.

Stratigraphical Details.

What has been stated on previous pages, when read with the aid of the accompanying map, will probably be found sufficient to convey all necessary information as to the general form and surroundings of this field. There remain to be described, therefore, only the stratigraphical details of the several rock groups which are represented.

The area of the field inclusive of outliers is exactly 97 square miles, the different rock goups being exposed in the following proportions :—

Mahadeva series		14·8	square miles.
Panchet	group	10·3	" "
Raniganj	"	8·8	" "
Barakar	"	58·5	" "
Talchir	"	4·5	" "
		97·0	

SECTION I.—TALCHIR GROUP.

As has already been stated, rocks belonging to the Talchir group are but sparingly represented in the Aurunga field. Except in the few instances about to be noted, the Barakars, where the boundary is natural, rest directly on the gneiss, having completely overlapped the Talchirs, which, it is to be presumed however, occupy the central and deeper part of the basin.

Commencing examination on the east, the first deposit of rocks of this age is exposed south of the village of Balunaggar near the road-crossing of the Sukri. The section discloses a false-bedded Talchir conglomerate with some red shales, the latter being perhaps of somewhat doubtful affinities. They are immediately covered on the southern bank by typical Barakar grits and pebble beds with white and pinkish clays.

Talchirs south of Balunaggar.

To the west of this there are two short exposures of Talchir shales in the bed of the river, which are interrupted by gneiss and partly overlapped by Barakars, which, farther on, completely conceal them. To the east of the road-crossing after an interval in the bed of the Sukri where no rocks are exposed, and at the junction of the three streams which combine to form that river, Talchir shales are again seen. In the first of these streams a section of about 200 yards long is exposed. The beds consist chiefly of yellow sandstones, but there are also some shales; they rest naturally on gneiss, and are covered up in the next three reaches of the southernmost tributary by sandstones, which gradually assume a Barakar-like aspect. Gneiss then occupies the section for about a quarter of a mile, after which the section discloses a narrow strip of Talchirs, consisting of liver-coloured shales and grey sandstones, with which a boulder bed of limited extent is associated.

The total area of the Talchirs, at this north-east corner of the field which are not concealed by overlapping Barakars probably does not exceed a quarter of a square mile. The precise extent is uncertain, owing to the boundary south of Balu-naggar being concealed by alluvium. The maximum thickness of Talchirs exposed in the above sections nowhere amounts to 100 feet.

Red clays at base of Barakars.

Proceeding round the eastern edge of the field, in the Bagh Digwa section north of Rampur, and at several of the points of junction in the Ghugree, north-west of Bhurla, there are red clays which may represent Talchirs; but they seem to be very intimately connected with the Barakar grits and sandstones, and are practically inseparable from them. On the south boundary narrow marginal strips of Talchir shales and boulder bed occur at the base of the sections to east and west of Mungur. Similar, but less distinctly seen, exposures occur in the bed of the Aurunga between Hurkha and Bishunpur.

On the northern boundary of the field between Latiahar and Nowadih, outside the east to west fault, there is a triangular-shaped area

occupied by beds of somewhat anomalous character, and the determination of the age of which was a source of considerable uncertainty to me.

Abnormal Talchirs at Latiahar.

The lithological characters are so unusual and peculiar that, until I met with some rather similar rocks among the Talchir beds in the narrow strip at the extreme end of the field, near Hosir, I was unable to bring myself to believe that they should be relegated to that age.

At the base of the section near Nowadih there are yellow sandstones exposed in the bed of the stream; these are overlaid by greyish yellow shales with some gritty beds, including one which is calcareous and contains small fragments of metamorphic rocks. With these shales there are thin papery carbonaceous layers, which confer a most un-Talchir aspect to the beds. The shales differ from ordinary Talchirs in being more fibrous and in seldom shewing the characteristic concentric structure and splintery fracture. In some respects they resemble more nearly certain beds which, in this area, have been referred to the Raniganj group, but the stratigraphical relations are such as to render it impossible to refer them to any group younger than Barakars.

They rest directly on the gneiss and dip steadily southwards towards the fault, the Barakars having the same general direction, modified by anticlinal rolls on the other side of it.

The occurrence of distinctly visible carbonaceous matter in rocks of Talchir age is not unprecedented, as I have already recorded a case which I met with in Sirguja, where there was actually a thin layer of coal of very inferior quality.

On the whole, it seems impossible to classify these rocks otherwise than as being Talchirs. The existence or non-existence of a fault does not materially affect the case, as from the dips the beds on the north must be older than those on the south.

South of the indicated line of fault which probably had a very slight downthrow here, the rocks, up to the foot of the hills, are much obscured by alluvium. This is particularly unfortunate, as the neighbourhood of

Latiahar is one where the relations of the beds is very intricate, and where a few really clear and unmistakable sections would be of great importance.

Talchirs at Bindee.

The last area of Talchirs in direct contact with the field forms a marginal strip of varying width, which extends along the south-west border of the field for about 9 miles from Godinan to beyond Hosir. Within its limits at Ledopali and Bindee there are two inliers of metamorphic rocks whose boundaries, though not very clearly exposed, owing to superficial deposits, cannot be very widely different from those indicated on the map. North of Bindee the Barakars appear to rest directly on gneiss without the intervention of any Talchirs. The Talchirs throughout this strip consist principally of shales and boulder beds, sandstones being less common.

Talchirs at Hosir.

At Hosir, as already mentioned, occur the sandy and fibrous shales already alluded to as being similar to the anomalous rocks at Latiahar. Here they occur on the same line of strike and in intimate association with distinct Talchir shales and boulder bed, leaving no doubt as to the horizon to which they should be referred. There is a good deal of disturbance all along the line of junction with the gneiss, the shales often dipping at angles of from 60° to 90°. I failed to detect any faulted contacts, and it seems most probable that this disturbance should be referred to the effects of the lateral crush which would naturally follow from the faulting of the Barakars on the north boundary of the field.

At the same time it is possible that there may be a continuation of the northern of the Latiahar pair of east and west faults in the gneiss of this neighbourhood.

Outliers.—Detached from the main area of the field, but in its immediate vicinity, there are two outliers, in which representatives of the Talchir group occur.

Outlier beyond Hosir.

The first of these consists of a narrow belt in broken continuation with the abovementioned marginal strip which is prolonged beyond the Barakars at Hosir. This

belt strikes in a south-westerly direction from Oopag for about 2½ miles towards Huratu. It is well exposed in section in the Jelma river, and consists of shales, sandstones and a strongly-developed boulder bed.

These in places are a good deal disturbed and crushed, but I saw no clear indication of any faulting having taken place.

Outlier north of Nowagarh.

The second outlier is situated to the north of Nowagarh. The character of the Talchirs here is best seen in a section which is exposed for about half a mile in the bed of the Sotapani between the villages of Kotilwa and Heslah. The rocks chiefly consist of soft yellow sandstones, which rather closely resemble those of Raniganj-age, and yellow shales. At Topo, and thence eastwards, they are covered up by the pebble conglomerates, and are overlapped by them, as they do not reappear along any other part of the boundaries of this outlier.

SECTION 2.—BARAKAR GROUP.

The rocks of Barakar age within the limits of the Aurunga field occupy several practically detached areas (the intervals being covered by younger rocks) which can be most conveniently described separately. These areas, therefore, will be taken up as they occur from east to west, or as they would be encountered by any one entering the valley of the Aurunga from Balumath. The shape of the first of these, which lies on the north-east, and from which a prolongation margins the field on the north, is too irregular to be intelligibly described, but with the accompanying map before the reader any such explanation is scarcely necessary.

Section in northern branch of Sukri.

The first section to be described is that which is exposed in the northern branch of the Sukri south of Balunaggar. Already the character of the beds seen at the road-crossing has been alluded to in describing the Talchirs. The conglomerates and white and pinkish clays extend thence eastward into the highlands where, in the neighbourhood of the already-described ridge of fault rock at Korean, they are locally much disturbed, dipping

at an angle of 40° to north. Farther east they rest on the limestones and other crystalline rocks. To the west of the road crossing, at a distance of rather more than half a mile, the section in the Sukri discloses a lenticular mass of decomposed coaly shale resting on about four feet of blue, pink and yellow shales, and covered by twenty feet of fine white sandstone.

At thickest, the coaly shale is 2 feet 4 inches, with a rolling dip.

Section east of Mooroop.

Beyond this the section alternately discloses Barakars, Talchirs and gneiss up to the point where the stream crosses the boundary, and does not re-enter the coal measures again until a point east of Mooroop is reached, where there is a section as follows :—

> Gneiss.
>
> Grits with quartz pebbles, dip 15° S. W.
>
> *Inside* the boundary, on the east side of the river, gneiss is exposed for 30 yards or so, and the contact is clearly natural.
>
> Overlying these bottom beds there are white and grey clays, dip 25° south.
>
> Interval.
>
> Sandstones, dip 20° S.

The map is here wanting in detail, as it does not represent a very decided loop bend in the river, in which flaggy, somewhat ferruginous, shales are exposed.

These beds possibly represent the Kolherwan ironstone zone to be presently described. Although the imperfection of the section prevents its being traced, it is most probable that close by here runs the continuation of an east to west fault, which is well seen in the west. And it is possible that to the cutting out by this fault may be attributed the absence in this section of the Rajbar coaly zone, which is described below.

Coaly zone cut out by fault.

The flaggy beds are followed by sandstones with their carbonaceous shales. These, east of Mungra, are covered by soft fine-grained yellow sandstones, which must be referred to the Raniganj group.

Raniganj beds.

In the neighbourhood of Kolherwan occurs the above-alluded to zone of shales and ironstones. The latter are disseminated rather sparsely in beds 2 to 3 inches thick, through perhaps 30 feet of grey sandy shales which rest on blue concretionary shales. Such is the section seen south of Patratu beyond which the extension is obscure, possibly the ironstones die out. At Lejang there are ripple-marked sandstones forming a small hill, dip 20° S.-W. Throughout a considerable portion of this neighbourhood, concretionary nodules of iron, weathered out from the sandstones and grits, strew the surface in great abundance.

Ironstones at Kolherwan.

In the southern branch of the Sukri[a] at Pukrar, the junction of the Raniganjes with the Barakars appears to indicate internal overlap in the former. In the north to south reach near the village the yellow sandstones dip steadily south at angles rising to 40°. Suddenly then at the village there is a roll which brings up Barakar sandstones with carbonaceous shale, the base of which is slightly coaly. There is no sign of any faulting, and the peculiarity of the section seems to be due to the topmost beds of the yellow (Raniganj) sandstone overlapping all below, thus resting directly on the Barakars. About half a mile east of Pukrar the section discloses some light-coloured sandstones and shaly beds, which are, I think, referable to the Raniganj group; they rest detached in a distinct synclinal of Barakar beds, and therefore constitute an out-lier. Proceeding eastwards, grits and sandstones with dip of 5° are underlaid by shales with poorly developed ironstone, which may possibly represent the Kolherwan zone. In the next reach south-west of Lejang, we meet the following section:—

Internal overlap of Raniganjes.

Raniganj outlier.

Section, descending, dip W. and W.-S.-W.

Grit	4' 6"
Grey shales	4' 0"
	8' 6"

[a] Whether there exist distinctive names for all the different streams which combine to form the Sukri I cannot say; it is most probable that there are, but the guides with me certainly applied the name Sukri both to the one south of Balu-naggar and that under description.

Brought forward		8′ 6″
Flaky sandstone		1′ 4″
Grey shales		1′ 6″
Sandstone		10″
Grey shales		3′ 0″
Sandstone		3″
Blue and black shale coaly towards base		4′ 0″
Sandy shale		3″
Blue shale		2′ 6″
Sandstone		8″
Grey shales		1′ 4″
Seam—		
Coal, decomposed	3″	
Parting	1″	
Coal, decomposed	1′ 0″	
Grey and blue shales	3′ 0″	
Coal	2″	
Carbonaceous shale, coaly	6″	
Grey shale	2″	
Carbonaceous shale, coal	10″	
Blue shale	8″	
Coal	3″	
Carbonaceous shale, coaly	1′	
		7′ 11″
		32′ 1″

Below this there are four bands of carbonaceous shale ranging from one to two feet in thickness. The lowest includes about one foot of poor flaky coal. Another lower seam includes about six inches of coal. In the next reach the beds locally bend round by south to east, and some of the carbonaceous shales are repeated. This seam, or, to speak more correctly, this zone of seams and carbonaceous shales, is again exposed north of Rajbar, whence it follows much the same course as the bed of the stream. By interpolation it has here so increased in dimensions that it is nearly a mile wide south of Kolherwan.

The following is the section of the beds measured in the reaches east of Rajbar:—

Section, descending, dip rolling S. W. 7°

South bank of river.

Surface soil.

Synclinal—

1.	Thin sandstone and sandy shale	6′	0″
2.	Carbonaceous shale, coaly		2″
3.	Same as No. 1	3′	8″
4.	Blue and grey concretionary shale	2′	8″
5.	*Coal*		1″
6.	Same as 4, but more carbonaceous in places	2′	4″
7.	Sandy bed, lenticular, maximum	1′	8″
8.	Same as 4	3′	0″
9.	Sandy concretionary bed with ironstone	3′	0″
10.	*Seam*— Consisting of carbonaceous shales, 72 feet at 10°	12′	6″
11.	Sandstones with concretionary ironstones	5′	0″
12.	*Seam*—		
	(a), Carbonaceous shales, much concealed, 23 feet at 10°	4′	0″
	(b). *Coal*, good		4″
	(c). Similar to *(a)* with sandstone interpolations, 26 at 10°	4′	6″
	(d). *Coal*, lower part very ferruginous	1′	0″
North bank of river—			
13.	Sandstone, with ironstone, about	5′	0″
14.	*Seam*— Carbonaceous shales with occasional layers of good coal up to 4″, and of inferior flaky coal up to 1′—195′ at 25°	83′	0″
15.	Sandstones with shales alternating, dip. 25° falling to 15°, say 58′ at 20°	19′	9″
16.	*Seam*—		
	Coaly shale . . . 1′ 9″		
	Flaky coal, decomposed . . . 6″		
	Sandy and concretionary shale . . . 2′ 4″		
	Coal, poor . . . 1′ 1″		
	Concretionary shale . . . 1′		
	Coal . . . 2″		
	——— 6′ 10″		
		164′	6″

Brought forward	164'	6"
17. Shales	7'	
18. Sandstone, say	12'	
[a] 19. *Seam*, badly seen— Upper half apparently fair coal, 50' at 15° . .	12'	10"
South bank—		
20. Sandstones	3'	
[b] 21. *Seam* similar to No. 14, 80' at 15° W.-S.-W . .	21'	2"
22. Sandstone	1'	
23. *Seam*, also similar to No. 14, 70' at 10° . . .	12'	2"
24. Sandstone		8"
25. Carbonaceous shales passing into blue shales . .	6'	
26. Sandstones and carbonaceous shales about 40' at 10° .	6'	10"
[b] 27. *Seam*— Contains thin bands of coal alternating with shale 140' at 10°	24'	6"
	271'	8"

Strong interpolations of sandstones modify the character of this last seam in its further extension towards Burwa toleh. The contrasts afforded by it as seen in section on either side of the river are very striking. Along the same line of strike to south-east I could find no further trace of these carbonaceous beds, and it seems probable that they die out.

Coal zone dies out to south-east.

Before reviewing the above, it will be well to give an account of the sections which flank this zone. North of Rajbar in the Bunora stream there is a broken section of some of the above as well also as of some lower measures. Being seen dry, instead of sodden with water, as is the case in the Sukri section, it is easier to form an opinion as to the quality of the seams. Coal is only seen in rare bands, the thickest of which does not exceed one foot.

In the Seruk stream which runs south of Rajbar and which joins the Sukri beyond Jorean, the section exposes at the base, resting on gneiss, sandstones and white shales, with a dip of 20° to west. These are

[a] A sample from this seam contained only 22·3 per cent. of fixed carbon, with 50·8 of ash.

[b] *Vide* Table of Assays.

overlaid by grits, sandstones, and blue and grey shales. At Hureyakur, ironstones, of which we shall have more to say presently, are seen in the banks of the stream. Soon, by interpolation, the highest beds of the carbonaceous zone make their appearance, and steadily increase in dimensions, and vary in character as we proceed down stream in a north-west direction. There are, at least, three distinct seams near Jornean with low rolling dip to south-west. To the north-west of Jornean again there are two more, the position of which with regard to the ironstones about to be described is uncertain, owing to the complications of the stratigraphical sequence arising from extensive interpolation.

Seams at Jornean.

Overlying the carbonaceous zone is a band of shales, with ironstones, which form a very marked north-west to south-east ridge for a distance of nearly two miles. From a section afforded by a stream south of the ridge, I am inclined to believe that, as a maximum, the ironstones are about 10 per cent. of the whole thickness of this zone. The actual thickness of the zone is somewhat doubtful, but as the average dip of the shales is about 5°, 200 feet is, I think, a fair estimate, so that where thickest there is probably a total of 20 feet of ironstones. At first sight, owing to the fact that the conservation of the ridge has been due to the presence of the ironstones, and that fragments of ironstone strew the surface in great abundance, it might be thought that the above was an under estimate, but I believe it to be a most liberal one. Now, as to lateral extension: towards the south-east the ironstones, like the carbonaceous shales, appear to die out rapidly. To the north-west at Jornean the ironstones are locally elevated into an anticlinal; their further prolongation is doubtful; a sharp turn to north of Jornean would bring them into connection with the zone at Kolherwan, but the occurrence of the seams north-west of Jornean renders it probable that these are continued and die out in the direction of Timkee, and that therefore the two zones are really distinct, being interpolated at slightly different horizons.

Ironstones south of Rajbar.

Altogether it may be confidently asserted that there is a plentiful supply of ore in this neighbourhood, which, as the dip is only 5° and less, might be easily worked. The quality of the ore too is satisfactory, a fair sample having yielded on assay 49·2 per cent. of metallic iron. So similar in appearance are these ironstone shales to the group of that name in the eastern fields, that it might easily be supposed that they are of the same age. The occurrence of Barakar sandstones, &c., however, higher in the sequence, indicates their true position beyond a doubt. Somewhat similar ironstones occur with the Barakars on the east of the Karanpura field. The true Ironstone Shale group I believe to be wholly unrepresented in the Aurunga field and its outliers. In one of the latter, as will be shewn, these Barakar ironstones are likewise strongly developed, forming a very important deposit.

Quality and quantity of the ironstone.

Ironstone Shale group absent.

We have then in tolerably close proximity to Rajbar coal, ironstone, and limestone (*vide* map). The quality of the two latter has already been described. Regarding the coal it will be necessary here to say a few words in anticipation of the fuller account which will be found in the chapter on the economic resources. The extent of the carbonaceous deposits here exposed could scarcely fail to attract the notice of a passer-by, and a vast supply of coal might be thought to exist; close examination soon reveals the poverty of the seams, and the assays which I have made of some of the best looking bands of coal have fully confirmed the unfavorable opinion which I formed in the field. At the same time I do not wholly despair of the existence of tolerable coal in workable thicknesses; but that coal suitable for iron-smelting will ever be found in this neighbourhood is, I regret to say, scarcely to be hoped for.

Coal of inferior quality.

A pit near the river bank east of Rajbar might easily be sunk to test these seams thoroughly. It is to be hoped that such may be done before any final conclusion is arrived at.

Trial pit.

Between Goortoor and Dunria, along the eastern boundary, the rocks are chiefly hill-forming conglomerates, with angular quartz, a small inlier of gneiss being surrounded by these beds. Ironstone concretions, weathered out on the surface, are here likewise very abundant. At Dunria the position of the boundary is somewhat doubtful. Between Dunria and Renchee I saw no sign of the carbonaceous zone. South of Renchee at the road-crossing, we have on the east Barakar grits, and on the west soft sandy beds of uncertain character, probably Raniganjes; beyond them come in grits which probably belong to the Panchets, but the position of the Raniganj-Panchet boundary is here somewhat uncertain.

Rocks on eastern margin of field.

In the neighbourhood of Rampur a series of streams afford a number of sections which throw much light on the geology. South of the village there is a well-marked faulted junction between the gneiss and some grits and shales which dip north at 20.° In the bed of a tank the beds appear to be nearly vertical. The fault strikes nearly due west from hence towards the Jugguldugga hills, and with the aid of a north-west to south-east fault, has cut a wedge-shaped area out of the field. The sole evidence of the former existence of the Barakars is afforded by a small outlying patch at Reharee which rests on the upheaved gneiss.

Sections at Rampur.

In the Bagh-digwa stream north of Rampur the bottom bed is a red arkose, upon which rest sandstone, grits and shales with dip of 35° to south-west. Following this stream westwards Barakar, sandstones are met with dipping in various directions. As the village of Hoochloo is reached, a tolerably continuous section is exposed, carbonaceous shales with portions slightly coaly dip south-west at 40°. Above these are sandstones and a few thin bands of ironstones, the quality of which is probably equal to that of the Rajbar ironstones. These are soon covered by rocks which must be referred to the Raniganj group, and are thus separated from the area of Barakars exposed to the south-east of Jugguldugga. We pass therefore again to the northern boundary, to describe the sections near Toobed, before entering upon an account of the Barakars on the south of the field

Section at Toobed.

North-west of Toobed, in the bed of the Sukri, there are the already mentioned sandy gneisses striking east-north-east, and 35° north of east; these have been cut into a deep gorge by the river, close to the mouth of which they are overlaid by red and white shales, after which follow a number of seams with dip to east. If not cut off by the east and west fault as is represented, we should here have evidence of great unconformity between these beds and the Raniganjes, but the fault, as will presently be shown, is very distinctly marked. The following descending section was measured in the reaches of the Sukri to east and north of the village of Toobed; though extending from the sandstones of Raniganj age to the gneiss, it is of no use as an absolute measure of thickness, as some beds of the Barakar sequence have certainly been cut out by the fault:—

Descending Section in the Sukri at Toobed.

North bank	Sandstones (Raniganj).		
	Interval, wherein the fault probably occurs.		
	Blue and carbonaceous shales with sandstones, perhaps 150' in all, but rolling and, where repeated, dip E.-S.-E. 10°.		
	Section—		
	1. Grit sandstone	4'	
	2. Blue shales and sandstones, very variable . .	10'	
	3. *Coal*		3"
South bank, opposite mouth of stream.	4. Same as No. 2, about	15'	
	5. *Seam*, shaly coal, dip S.-E. 10° < 15°	10'	
	6. Sandstones and shales	8'	6"
	7. *Seam*, 850' at say 5° = ...	77'	0"
	This seam, nearly flat in places, certainly contains some fair coal, but owing to its sodden decomposed condition it is impossible to give details. Dip changes from S.-E. to E.-S.-E.		
North bank	8. Shales	4'	
	9. *Seam*, covered, about 100' at 5° = ...	8'	8"
	10. Yellow and white shales	5'	

North of 2nd stream.

11. *Seam*, 8′ vertical, 110′ at 15° E. = . 36′ 6″
contains about ¼th of burnable coal, separated in bands, none of which exceeds one foot in thickness.
12. Blue and white shales, 150′ at 8° = . . . 20′ 10″
13. Red and yellow shales resting naturally on . . 4′
Gneiss, vertical, strike 35° north of east.

Samples of the coal in Nos. 5 and 11 have yielded on assay but poor results, the percentages of ash being respectively 34·6 and 25·6.[a]

In the streams to the north of this section the beds are somewhat better seen, and the poor shaly character of the seams is more clearly apparent than where they are sodden with water in the bed of the Sukri. Here too I am forced to state my belief that there is not much prospect of a really good quality of coal being found in sufficient quantity to be mined with profit. Proceeding westwards along the bed of the Sukri, the section passes abruptly from the above-mentioned gneissose rocks into a narrow zone of intensely tilted ripple-marked sandstones with carbonaceous shales, which are seen tobe in vertical faulted contact with the gneiss in several junctions exhibited in the small tributary streams. In the Sukri itself the ripple-marked beds dip 55° to south and south-south-west, and are covered up immediately by yellow sandstones and some blue, slightly carbonaceous shales belonging to the Raniganj group. Just beyond the village of Bandudag the Barakars are completely cut out by a fault, but immediately reappear with some Raniganjes in a cut-off patch, to the north of the fault,—*vide* map.

Disturbed section west of Toobed.

The section of this cut-off patch west of Bandudag is particularly well seen in the Sukri, and exhibits a peculiarly interesting piece of geological structure. Underlying the yellow Raniganj beds, there is in the first section a very narrow belt of nearly vertical grits with red clays in *natural* contact with the gneiss. These are, therefore, the bottom beds and represent, in this particular spot, the whole thickness of Barakur

Section in Sukri west of Bandudag.

[a] Vide Table of Assays in chapter VII.

beds, which, it is needless to observe, have very much thinned out. Passing the loop bend occupied by metamorphic rocks, the next section of the Barakars is in the vicinity of the mouth of the Katari, where there is a seam, not very well seen, which is overlaid by sandstones and grits, and these, within a short distance, by the yellow sandstones of the Raniganj group. Under this seam are some red beds which, in one spot on the south bank, rest on decomposed gneiss, and for a short distance the junctions with the gneiss are very irregular, the sections of the bottom beds on either bank of the river exhibiting striking contrasts.

In the next reach, from south to north, the following section is met with :—

Section in loop bend of Sukri north of Manjhar, dip to south, and 10° east of south (descending).

(1). White shales and grit with one 4-inch band of coal about centre	10′	0″
(2). *Seam*—		
Does not appear to contain any good coal, but is much decomposed, dip 30°	15′	0″
(3). Blue and white shales, 70′ at 30° = ...	35′	0″
(4). *Seam*—		
Consists of alternating thicknesses of concretionary shale and papery coal of from 2″ to 8″, the latter about one-third of the whole thickness, 18′ at 30° = ...	9′	0″
(5). Mottled and concretionary shales, portions passing into grit, 17′ at 30° = ...	8′	6″
(6). Blue (carbonaceous), white and mottled pink, concretionary shales, 83′ at 17° = ...	24′	2″
(7). Similar beds, more carbonaceous in places, 100′ at 20°=	34′	2″
There is a transverse slip in the above beds which does not, however, affect the above measurement.		
(8). Mottled grits passing into shales, 32′ at 25° = . . .	13′	6″
(9). Carbonaceous shale, seen	2′	0″
(10). Interval 120′ at 25° = ...	50′	7″

(11). Same as 8	10	0″
(12). Red (liver-coloured) and greenish shales, 100′ at 25° .	88′	7″
Gneiss		
	300′	6″

If 50 feet are added to the above, the total, 350 feet, will give as near as possible the *maximum* thickness of Barakars cut off north of the fault. The *minimum* thickness probably does not exceed 20 feet.

It may be that these liver-coloured clays, No. 12 of section, represent Talchirs. Though occurring at most of the natural junctions, they are nowhere so well developed as in this section. In some cases they occur not actually as bottom beds, but are underlaid by sandstones or grits, which seem properly referable to Barakars. Though it is true they are somewhat an unusual form of rock to meet with in Barakars, they differ from Talchirs both in texture and mode of fracture.

Section at intersection of faults.

The last section of these rocks which is seen in the Sukri, though short, is a very interesting one, as it affords evidence of the intersection of the two faults at the precise spot where from their directions further east it was concluded that they would meet. In the angle included between them, the Raniganjes are let down in a V-shaped trough, a seam of carbonaceous shale, which is clearly seen on the south side of the V, is cut out by the east to west fault on the north, and the edges of the beds brought into contact with those of the cut-off Barakars.

Areas south-east of Pochra.

The next areas of Barakars to be described are those which occur to the south-east of Pochra, and are included in the angle formed between the northern of the pair of Latiahar east-west faults, and the great north-west south-east fault. The rocks mainly consist of coarse grits with a large amount of concretionary ironstones. In the raviney ground south of Subano, the streams shew indications of the existence of a patch of Raniganjes cut off by the fault. As near as possible the limits of this patch are given on the map, but the relations are not very clear. The

faulted junction is clearly seen in the streams south-west of Subano, where the coarse grits are in contact with the greenish Panchet sandstones. The general form and position of these areas will be best understood by reference to the map.

Section in Ghugri.

Resuming description close to where the Barakars were described as being covered up by the higher groups near Hochloo, in the region lying to the south-east of Jugguldugga, the first section to be mentioned is that afforded by the Ghugri. In this river between Rukhunt and a point south of Sukri the rocks are, for the most part, concealed by alluvium, and the precise position of the boundaries is somewhat uncertain in consequence, but they cannot be very different from what is represented. South of Kurmahi the effects of the great north-west south-east fault are marked by the steep and abrupt tilting away from it of some sandstones, grits and shales which dip at angles of 50° to 70° to south and south-south west.

Gorge north of west of Bhurla.

A little to the west of north of Bhurla the river has cut a deep gorge through massive sandstones and grits which dip to north-east and north-north-east at angles of from 20° to 30°. A little farther on, north of Nowatolah, the boundary strikes a loop bend tangentially, and a section is disclosed shewing a massive pebbly grit resting with original contact on the face of thin purple sandy gneiss. After this the river runs with the line of junction of contorted gneiss with south-east dip, exposed on the south bank, and sandstones dipping away on the north.

Beyond this about seven bands of carbonaceous shales appear by interpolation. They do not include any coal. Several very pretty natural junctions which have been affected by lateral thrust are then met with at intervals, but the detailed description of which would occupy too much space here. It must suffice to allude to one only. This is where the boundary crosses the Aurunga river north of its junction with the Ghugri.

The difficulty about this section is to ascertain sharply the line of junction between the decomposed metamorphic beds and the sandstones, &c., which are largely formed of gneissose materials. On the right of the section a massive pebble bed rests on the edges of the disturbed and decomposed gneiss, while on the left red clays and white and ferruginous grits with much false bedding occur next the gneiss.

Section in Aurunga.

In the next reach we meet with the following well exposed section, the dip throughout being *q. p.* north :—

Ascending section in Aurunga River, south-east of Jugguldugga.

(Gneiss partly epidotic and decomposed; might be mistaken for Talchirs.)

1. Coarse grits, with shales, strike east-west q. p.	100′	0″
2. Decomposed carbonaceous shale (details not seen), 50′ at 65°=	45′	3″
3. Shales and thin sandstones, with some carbonaceous shale, much covered, 100′ at 65° > 35°=	76′	7″
4. Sandstones and grits, 120′ at 35° < 55°=	84′	9″
5. Decomposed carbonaceous shale, say	3′	0″
6. Grits, 60′ at 45°=	42′	5″
7. Interval, 40′ at 50°=	30′	6″
8. Decomposed carbonaceous shale, 33′ at 55°=	27′	3″
9. Thin false-bedded sandstones, with blue shales, 50′ at 57°=	39′	7″
10. Coarse grits, with interbedded shaly sandstones, 25′ at 60°=	21′	5″
11. Sandstones, 44′ at 60° > 50°=	31′	1″
12. Same as No. 9, 71′ at 60°=	61′	4″
13. Decomposed carbonaceous shale, 23′ at 60°=	19′	10″
14. Interval, bed of river, 120′ at 60° > 50°=	98′	3″
15. Sandstone and grit	6′	0″
16. *Seam*, including 1′ 6″ of *coal*	8′	0″
17. Shales and sandstones, 100 at 60° =	86′	7″
18. Thin sandstone with carbonaceous and blue shales alternating, 150′ at 50°=	114′	10″
19. *Seam*, includes thin layers of *coal*	8′	0″
20. Similar to 18, but less carbonaceous, 200′ at 50°=	153′	2″

21. Interval in bed of river, 100' at 50° > 35° = .	68' 0"
22. White sandstones and grits, with blue shales, say .	50' 0"
Total	1,195' 10"

The beds included in No. 22 might pass for Raniganjes, but in the high ground north of river there are grits and ironstones, higher in the sequence, which are, I think, clearly of Barakar age. If we add for these higher beds 300 feet, a most liberal allowance, the total thickness would amount to something under 1,500 feet.

Maximum thickness of Barakars.

In succeeding sections of the narrowing Barakar zone there is clearly no room for the full thickness above given, and here there is no trace of the overlying yellow beds, which may overlap in the sections measured below; but this would not account for the fact that between these beds (No. 22), where last seen, and the gneiss, there is not room for more than 200 feet as against about 1,000. This indicates great thinning out and internal overlap; in fact, in the succeeding sections the carbonaceous zone is scarcely represented. But the sections below measure 256' 7", rising to 559' 4" as we proceed eastward, and shew a decided tendency in the beds to recover this lost thickness. The thinning out of the carbonaceous zone here resembles its disappearance south-east of Rajbar.

Thickness in other sections.

Some of the decomposed seams may contain coal, but their appearance is not promising, and as their dip averages 60°, their economic importance is slight.

The sections above alluded to are as follows :—

Section in west reach of loop, south-west of Jugguldugga.

(Gneiss seen on south bank of river.)

1. Bed of river, rocks concealed, say	70' 0"
2. Sandstones, shales and grits, 125' at 70°= . .	117' 6"
3. Massive grit, dip 65°	9' 0"
4. Seam, decomposed	10' 0"
5. Grits and shales, 60' at 65° > 50°=	50' 1"
Total	256' 7"

Resting on the above are soft white sandstones with shales and grit. These seem to belong to the upper group (Raniganj). Their junction is disturbed by a roll. Thickness, say	30′

Section in reach north of Jaloom (Zalim.).

Gneiss, dip 70° . . . .

Barakars.	1. Massive grit, 1 foot arkose at the base, 90′ at 45° N.-N.-W.=	63′	7″
	2. Grits, with blue shales, 80′ at 45°=	56′	6″
	3. Same, 100′ at 65°=	90′	7″
	4. Grits, with sandstones and fine shales, 250′ at 55° =	204′	8″
	5. Concealed, 300′ at 30°=	150′	0″
	6. Grits	20′	0″
	Total	559′	4″
Probably Raniganjes.	7. Yellow sandstones, false-bedded, 280′ at 20°= . . .	95′	8″
	8. Yellow sandstones, with lenticular calcareous sandstones and carbonaceous shale at base, 300′ at 30°=	150′	
	9. Sandstones and carbonaceous shales	12′	10″
	10. *Coal*		3″
	11. Same as 9	12′	10″
	12. Concealed, 350′ at 15°=	90′	7″
	Fault (?)		
	13. Grit 10° N.-N.-W.	15′	0″
	Total	377′	2″

Section in Bagh Digwa River, east of Jugguldugga Hills.

Red and green clays and white sandstones; Dip, 25° south-west (Panchets).

Yellow massive grit sandstone; Dip, 20° south (Mahadevas).

Fault, no junction seen.

Barakars (*descending*).

1. Thin sandstones and blue shales, N.-N.-W. 15° . . .			35′	0″
2. *Seam*—				
(*a*). Blue shales	1′	0″		
(*b*). Papery coal		3″		

(*c*). Blue shales	3' 4"	
(*d*). Papery coal	2"	
(*e*). Blue shales	2' 4"	
(*f*). *Coal*	6"	
(*g*). Carbonaceous shale	10"	
(*h*). Blue shale, with coaly layers	6' 0"	
		14' 5"
3. Sandstone, ferruginous at top		2' 6"
4. Blue shales and white sandstones, base concealed, dip N.-W., 15°, say		7' 0"
Total		58' 11"

In the next reach the above beds, modified in character and relative thickness, are again seen. The coaly portions, which are better exposed, are in mere strings.

In the reach again next following there is further modification. No. 4, is reduced to about 4' 6", and consists chiefly of blue shales and coal, alternating every 3 or 4 inches.

Brought forward	58' 11"
Grits, dip W. N. W. 15°	6' 0"
Blue sands and carbonaceous grit	2' 0"
Total	66' 11"

In next reach we find the junction with the Borasukwa stream where Nos. 1 and 2 are repeated, No. 1 being thicker and more varied in character, including massive sandstones and thin layers of carbonaceous shale, and No. 2 slightly more coaly, dip 10° to 30° west of north.

In the reach next beyond the junction these shales include one band of coal 1' 6";[a] besides this there are several thinner seams with varying thickness of coal.

[a] Table of Assays of Coal in chapter VII.

So great is the difference in appearance in this part of the section, that it is difficult to regard it as representing the same horizon as that to which Nos. 1 and 2 belong. As No. 1 is not really the highest bed, but only apparently so in consequence of the faulted junction with the Mahadevas, it follows that we get higher beds to the dip.

The section of these in the next reach, dip, 15°, to 30° west of north, is, (*ascending*)—

(a).	Carbonaceous shales, with coaly layers . . .	30′ 0″
(b).	Sandstone, parting	1′ 6″
(c).	Same as (*a*)	18′ 0″
(d).	White sandstones	25′ 0″

The descending section is again resumed in the reach beyond the junction with the Sukri stream: sandstones, N.-N.-W. at 60°. These correspond to No. 10 of the Aurunga section on p. 73, so that the modifying effects produced by interpolation receive further illustration here by comparison of the beds in the two sections which have been measured above that horizon.

Last exposure of carbonaceous zone.

Although I shall have to mention some seams which occur in the country further west, this is the last strong development of the carboniferous zone in the Aurunga field. It does not, I am sorry to say, give any better, indeed not even so good a promise, as did the Rajbar section, of including any valuable seams.

Area west of Zalim.

The next area to be described is that which lies west of Jaloom or Zalim, and is traversed in part by the Gowa and Aurunga rivers. The section in the Gowa river is not very perfect; there are a number of seams of carbonaceous shales parted by sandstones; some of these contain coaly layers, but none are clearly exposed. One fragment of loose coal 3 inches thick was bright and of excellent quality, but I failed to find the source. The dips of these seams average 10° to north, but in places they roll a good deal.

They are not likely to include a workable thickness of coal, but should it ever be desired to test them, a boring or trial pit west of the village of Gowa would prove their quality.

Seams probably of no value.

In the Ghotwa river some thin carbonaceous shales occur, resting immediately on a narrow marginal zone of Talchirs.

At Hurkha there is a local development of ironstones of no great extent.

The bed of the Aurunga up to Dhudwa is frequently traversed by the boundary. In several cases the lowest beds are yellowish sandstones, apparently Talchirs. The sections of Barakar sandstones offer no particular points for note, save that anticlinal and synclinal rolls are very abundant. The map will serve to explain the nature of the faulted junction, shewing how the Mahadevas have been let down into contact with the three older groups respectively at different points along the line.

Section in Aurunga.

In the neighbourhood of Latiahar and thence westward the Panchet and Raniganj groups have disappeared, and the thickness now existing of the Barakars is certainly very much less than in the east. How far this is to be attributed to original limitation of deposit, how far to subsequent denudation, it is not easy to say. It is quite probable that the upper groups never were deposited so far west; and, on the other hand, it seems not unlikely that some portion of the Barakar sequence has been denuded away, though it may be difficult to prove the same. Be this as it may, it is certain that an outlier of Mahadevas rests directly on sandstones and conglomerates, whose lithological characters resemble those of the rocks forming the lowest zone in the east of the field. The Barakar rocks near Latiahar, so far as they are seen, shew signs of considerable disturbance, due no doubt to the proximity of three lines of fracture, *viz.*, a pair of east and west faults, and a cross-fault which bounds the field up to Putkee.

Barakars at, and west of, Latiahar diminished in thickness.

From Dudwah westward the Aurunga winds to and fro across the boundary, so yielding interrupted sections of sandstones and carbonaceous shales, which for the most part dip at high angles northwards. No coal is seen in this portion of the Aurunga or its tributaries. In the succeeding reaches of the Aurunga up to Putkee, sandstones, with rare carbonaceous shales, are the only rocks seen. At the three points, *vide* map, where the boundary strikes the river tangentially, the sandstones are either vertical or dip away at high angles. In the section west of Putkee the junction is undoubtedly faulted, and some pebble-beds shew signs of partial vitrification. Half a mile further on the river enters an oval tract occupied by an outlying basin of Mahadevas, presently to be described; where it again passes into Barakars, it discloses a narrow zone consisting of sandstones and conglomerates, with one band of carbonaceous shale, which dip S.-S.-E. at angles rising from 25°, to the vertical. Although it is clear that both here and on the southern margin of this basin the thickness of the Barakars is reduced to 200 feet or so at the utmost, none of the sections give distinct evidence of unconformity. In each stream, on the other hand, there seems to be a steady sequence upwards from the Barakar grits to the red Mahadeva sandstones. In the extreme western extension of the field, white pebble conglomerates, without any very distinct bedding, and forming series of low hills, prevail over every other form of rock. There still remain to be described the Barakar rocks of several outliers in the vicinity of this field.

Aurunga section continued.

No distinct evidence of unconformity.

Outliers.—Four detached deposits which include Barakar rocks are known to exist in the vicinity of the Aurunga field. By far the most extensive, and in other respects the most important of these, is situated beyond the north-east end of the field, and at an elevation which must average 200 feet above the level of the neighbouring portions of the field south of Balu-naggar. A very complete section of this area is afforded by the stream which, starting from Buruhmoria, runs round

Outlier at north-east end of field.

by Palee and Dudhuria to Khuriadih. The bottom beds, seen in the section, south of the first-named locality, consist of a ferruginous conglomerate, with angular fragments of quartz, dip 20° west, covered by clunchy white and grey shales, ironstones and carbonaceous shales. The principal bed of the latter includes some coaly layers, but only a thickness of about one foot is exposed. Close by this section, in the high ground east of Sirka, there is a low range about 50 feet high, half a mile long, which is made up of ironstones, including a fair proportion of excellent quality.

Ironstones at Sirka.

The whole surface of this range is honeycombed with holes, made for the purpose of extracting the ore. Resuming the section in the stream south of Sirka, there are sandstones, with white beds and ironstones; gneiss then interrupts the continuity, after which there is a much disturbed section of white and grey shales, with carbonaceous layers and ironstones in abundance, some of which are 5 inches thick, and have yielded on assay 45·3 of metallic iron.

Ironstones in river section.

West of this there is another break in which gneiss occurs; the stream then traverses sandstones with low dips to west and north-west, changing further on to the east. After an interval, the next rock exposed near Dudhuria is a seam consisting chiefly of carbonaceous shale of uncertain thickness; it is followed by another, and then they are repeated, and a third exposed, by a dome-like roll of the beds. The descending section of this dome, taken on west side, is as follows:—

Seams of carbonaceous shales.

Seam, very shaly *coal*, includes thin band of ironstone, 50′ at 20° W. = ...	17′	1″
Interval.		
Seam, 130′ at 20° W.-S.-W. = ...	44′	4″
Sandstones, with carbonaceous shales.		
Seam, 160′ at 15° W.-N.-W. = ...	41′	4″

The details of these seams are not clearly seen, but I do not think it probable that there is any workable thickness of good coal; however, as the occurrence of good coal in this vicinity, owing to the proximity of

the ironstones, would be of considerable importance, it would be advisable to sink a couple of trial pits in order to thoroughly test the seams. Higher in the sequence than the beds forming this dome, there are carbonaceous shales with ironstones; these are well exposed in the face of the river bank, where, in a thickness of about 30 feet, 10 per cent. consists of layers of ironstone, which are never more than 6 inches thick. The individual layers have not a wide extension, being of lenticular shape; but as they die out and reappear by rapid interpolations, the total thickness at any particular spot is pretty constant. A specimen of black-band ore from this locality yielded 33·7 per cent. of metallic iron. From this northwards up to Koriadih the section is much interrupted, occasional outcrops of sandstone only being seen.

Ironstone at Dudhuria.

Black-band.

To the west of this line of section there is at Ghotam a low range about a mile long, which, like the one at Sirka, is chiefly formed of ironstone. A specimen of Ghotam ore yielded 39·4 per cent. of iron; but the richest ore was obtained from some borings half a mile west of Kurmahie, the yield of iron being 56·6. Various other sections of these rocks were examined on the edge of the scarp near Ghotam and Dudhuria, which it is useless to describe in detail here; but it should be mentioned that there are caps of sandstones and conglomerates on the semi-detached hills near Balu-naggar.

Ironstone at Ghotam.

Ironstone at Kurmahie.

There is so much irregularity of stratification, that it is difficult to assign a definite thickness to this deposit, but where greatest it may be 300 feet.

The general ascending sequence appears to be—

General sequence.

Angular conglomerate.
White and grey clays.
Carbonaceous shales.
Ironstones.
Sandstones.

These sandstones I believe to be of Barakar age, and the ironstones, like those of Rajbar, must therefore be referred to the same group. No

traces of Talchirs were met in this area. The prospect of the seams of carbonaceous shales being found to contain good coal is very slender. This is the more to be regretted since ironstone of good quality is in great abundance, and the crystalline limestone is close by. The area of this ironstone field is about 4 square miles.

Outlier north of Mariatu.

The next outlier to be mentioned is found north of Masiatu, and consists of clays, sandstones and conglomerates, which occupy an area of less than half a square mile. These are perched on a very irregular pedestal of metamorphic rocks, the elevation of the lowest beds varying within 100 feet in different sections. This deposit offers no particular points for further notice.

Outlier north of Nowagarh.

The third outlier is situated beyond the southern boundary of the field near Nowagarh. It occupies about 2 square miles, in about half of which Talchir rocks are found. These are only exposed on the west, being overlapped on all the other sides. The Barakar beds consist of sandstones and conglomerates similar in character to those of the adjoining parts of the field. There are only traces of carbonaceous shales, and the rocks generally present no particular points of interest.

The last outlier occurs just outside the boundary north of Toobed; the rocks are red shales, and occupy a very small area.

SECTION 3.—RANIGANJ GROUP.

There are few clear sections of these rocks exposed, and as they shew a departure from the normal lithological characters of the group in a comparative scarcity of calcareous bands, and a prevalence of soft yellow sandstones not unlike those occurring in the next succeeding Panchet group, it has not always been easy to discriminate them.[a] The boundaries which have been drawn therefore must be understood to be, to a great extent, arbitrary.

[a] Some of these yellow beds particularly reminded me of the Panchet sandstones of the Damuda section in the Raniganj field at Deoli, where the reptilian fossils were found.

No fossils have been discovered in them, and the correlation is therefore wholly established by geological position and lithological resemblance to beds in the adjoining Karanpura field.

No fossils. Correlation by lithological and geological characters.

In the Sukri, west of Mungra, the Barakar beds are covered up by soft yellow false-bedded sandstones, with rare bands of calcareous sandstones. The transition to the Panchets is not well marked, and the position of the boundary consequently doubtful. In fact, when first examined I thought I had but one group to deal with. The dip of these yellow beds averages 15°, and the thickness I estimate here at from 900 to 1,000 feet. In all other sections it is probably less.

Boundaries doubtful.

Thickness.

In the southern branch of the Sukri occurs the already described junction near Pukrar, which appears to indicate internal overlap in the Raniganjes. Another section of these beds is afforded by the Sukri near Toobed. Resting on the Barakars there are fine sandstones with a dip of 8°, to east-south-east; these are followed by yellow sandstones which dip 15° to south-east, and soon becoming flat are covered by alluvium, so that the topmost beds of the sequence, underlying the Mahadevas, are not seen. It is possible that the beds so covered are Panchets, but immediately south of the village the Mahadevas come so close that these highest beds must be overlapped. The next section is in the Sukri west of Toobed, where, resting on the previously described highly tilted ripple-marked Barakar sandstones and carbonaceous shales, there are yellow sandstones, with carbonaceous shales, having the same dip of about 55°. These are succeeded by fine yellow sandstones and sandy shales, with dips falling from west-south-west 42°, to west 15° and west 5°, upon which rests a bed of gritty sandstone that should probably be regarded as the base bed of the Panchets; resting upon it there are gently rolling greenish and

Section near Toobed.

Panchets overlapped by Mahadevas.

Sections west of Toobed.

purple clays of typical Panchet character, after which we pass again on to yellow sandstone, of which numerous sections are afforded in the streams near Bundodag, where, owing to the vicinity of the fault, they dip at angles of 50°, and even 70°. In the small area cut off by the fault, bluish carbonaceous shales, as in the previous section, are associated with the yellow beds, which appear to be generally conformable to the underlying Barakars, to which however they present the strongest contrast in lithological characters. At the extreme end of this portion of the field, where the two faults (*vide* map) intersect, these beds have been squeezed into a V-shaped trough, on the southern side of which a portion of the beds have been cut out by the east-west fault, as it is only on the south side of the V that a seam of carbonaceous shale is seen, measuring 9′ 6″, dip 50°. There is undoubtedly a zone of Panchet beds round the Sasung hill, but the sections are not very clear.

Section in Bagh Digwa, west of Hoochloo.

We now pass to the section in the Bagh Digwa near Hoochloo. Overlying the Barakar section there, a series of steeply inclined sandstones apparently belong to this group. These are soon covered by coarse gritty beds, which I should be inclined rather to refer to the Panchets, but it is not clear how they can be so, as further west there are, at an apparently higher horizon, calcareous sandstones of the well-known Raniganj type. It is possible that some of the beds higher in the sequence may mark a tongue of Panchets along the line of fault, but as the plotting of the river is very defective, I have not attempted to indicate this. On the other side of this fault there is a narrow strip of red clays belonging to the Panchets, which are soon covered by Mahadevas.

Sections near Jugguldugga.

To the west of this, surrounding Jugguldugga, there is a patch of Panchets cut off by the fault, which are themselves surrounded by a narrow marginal zone of Raniganjes. These are of typical character, and include calcareous bands in the section seen in a small stream south-east of the village. In the loop bend of the Aurunga south-west of the village there is a small section of rolling sandstones of this group which rest on the much

diminished zone of Barakars. In the next loop bend of the Aurunga to the west there are similar sandstones, and with them some carbonaceous shales. Those at the north end of the reach are in crushed contact with a peculiar massive white grit which has some resemblance to Barakars, but must from its position, I believe, be referred to the Panchets.

Raniganjes thin out.

In the Aurunga west of Gowa the Raniganj beds are not clearly seen, but they must have thinned out considerably, since they are restricted to a very narrow zone between the purple Panchet clays and certain grits, which must, I think be regarded as Barakars. These sections and the one above described in the Sukri where the faults intersect are the most western points where rocks exhibiting the standard Raniganj lithological characters have been met with. It seems most probable that, where rocks of this age are met with further west, they will be found to have assumed the lithological character which distinguishes the Kamthis.

It is singular that the change should be found so distinctly to the west of the watershed of the Damuda. I have already endeavoured to explain this on a previous page.

Areas north of Jugguldugga.

There still remain two small areas of these rocks to be described; they are situated in the raviney ground north of the Jugguldugga hills which is drained by the Subano river. The limits owing to the nature of the ground and the want of striking contrast between some of the beds of the two groups are often very obscure. The most noteworthy fact is that they include the only seam of real Raniganj coal met with in this field. The seam is only 1′ 6″ thick, dip 25°. The quality of the coal is indicated in the table of assays. It turns out to be a worse fuel than I had expected from its appearance and lightness. There are other minor seams close by. The principal associated rocks are dense, micaceous, calcareous, fine-grained sandstones and loose soft sandy shales, some of them not very distinctly separable from the rocks which occur in the region between Udipura and the Jugguldugga hills, and which I have referred to the Panchet group.

Coal seam.

SECTION 4.—PANCHET GROUP.

In the previous section the indication of the limits of the Raniganj group has involved frequent allusion to these rocks, the distribution of the two being very similar and co-terminous. The generality of the sections tend to shew that the two groups are conformable in most cases, but there are several which make it doubtful that this conformity is universal, notably the two sections just described in the Sukri west of Jugguldugga; and if the soft greenish beds, which at Deobar underlie the eastern end of the Mahadeva outlier beyond the Aurunga, are Panchets, there is evidence of very complete overlap, as there is no trace of the Raniganjes in that section.

Conformity to Raniganjes.

There are several leading lithological types among the rocks which go to make this group. Of these, the highest are the purple and green clays and associated shales. These are somewhat local in their distribution, being only found in the Sukri section near Kaima in the Bagh Digwa, west of Hoohloo, and in the Aurunga north of Kaima.

Lithological types.

The next types are grits, of which there are several varieties, some loose and ferruginous, others soft, greenish and friable, and still others which are white and felspathic, and are not easily distinguishable from Barakar rocks. At first I thought that the generally undecomposed condition of the felspar furnished a means for distinguishing these from Barakars, in which the felspar is usually in a decomposed condition and more generally disseminated. This does not always hold good, as Barakar grits, including angular fragments of undecomposed felspar, were subsequently met with. Rocks of either of the above types are not likely to be mistaken for Raniganj beds, but there is still another type, or rather class, exemplified by greenish micaceous sandstones, occasionally calcareous. To distinguish these from very similar beds in the Raniganj group is by no means easy, and this the more especially as they occur at the base. To this cause is to be attributed much of the doubt which must always attach to the determination of the precise position of the Raniganj-Panchet boundary.

Carbonaceous matter.

In one place only in the Sukri section near Semuria did I meet with any case of the occurrence of carbonaceous matter in these rocks; the traces of it were very slight, being little more than black stains. A constant outlook for fossils in these beds did not result in the discovery of a single fragment. Some of the thin micaceous shaly sandstones resemble the *Estheria* beds of the Raniganj area, but I found in them no trace of any organic remains.

Fossils.

Overlap by Mahadevas.

From the varying width of the zone of these rocks found surrounding the base of the Mahadeva hills, the probability that they are in places overlapped is very great. Indeed, at Toobed, this seems certainly to be the case; but besides this overlap unconformity there is, I believe, in the sections afforded by the streams in the valley between Hurdee and Chehora hill, south-east of Subano, evidence of regular disturbance unconformity: there is a steady dip southwards of a thickness of several hundred feet of the Panchets, almost up to the very foot of the Mahadeva scarp. There is certainly not interval sufficient for this whole thickness to be turned over so as to dip normally under the Mahadevas.

Disturbance unconformity.

Since, as I have shewn when treating of the Mahadevas generally, there is great probability of a considerable break in conditions of deposition, if not of time, between the Mahadevas and all preceding groups, the wonder is that there should not be more numerous cases of unconformable superposition to be enumerated.

The estimated thickness of the Panchet group in this area is 700 feet.

SECTION 5.—MAHADEVA SERIES.

The principal area in the Aurunga field, occupied by these essentially hill-forming rocks, is a raised tract, extending in a north-west south-east direction for a distance of over six miles from Kaima to Hurdee. The beds dip inwards from the opposing scarps at angles of 20° and under, so forming a synclinal trough, at the centre of which the beds are for the most part horizontal.

The maximum thickness does not exceed 500 feet in all probability,

Thickness.

The rocks, as seen in the sections near Subano, consist primarily of dark reddish-brown, ferruginous sandstone, with extremely sparse strings of iron-stained quartz

Lithological characters.

pebbles, and occasional thin partings of dense red clays; there are also white loose-textured grits, from which the iron has been segregated into dense ferruginous plates.

The physical characters of these rocks have been sufficiently indicated

Physical characters.

in the general sketch, and the overlap of the Panchets at Toobed, and the unconformable superposition on the same rocks to south-east of Subano have also been described. To the north-west of this hilly tract there is an outlying low hill near Sasung formed of these rocks. The beds rest upon Panchets, and are cut off by the fault on the south-west. The thickness is inconsiderable, probably under 100 feet.

The next area occupied by rocks of this age is situated near Jugguldugga,

Area near Jugguldugga.

and is about one square mile in extent. It is partly included between two of the main faults of the area, and the lowest beds are in consequence in contact with the edges of beds belonging to several different groups. These relations will be best understood by reference to the map. The rocks are pre-

Thickness.

cisely similar to those just described; the thickness of the beds is at present perhaps about 450 feet; they form a synclinal basin, and, as is almost invariably the case

Perennial streams.

with the Mahadevas, they are most efficient water storers. Perennial streams are almost invariably to be found in their vicinity. This I also remarked upon in reference to the Kamthi rocks of Hingir.

The next area is situated to the west of the Jugguldugga hills, ex-

Area east of Latiahar.

tending thence to Latiahar. A good section is obtained in the deep-cut gorge between Satodeeh

and Keenamand. The straightness of the boundaries, together with the varying nature of the contact beds, sufficiently prove the existence of a pair of bounding faults.

Bounded by faults.

This is further evidenced by the high inclinations of the beds, dipping from the faults on both sides, which thus form a very decided synclinal trough. I have already spoken of the obscurity of the relations near Latiahar. The rocks near the base of the hills are completely concealed by alluvium, but if I am right in relegating the anomalous beds to Talchirs, I think the relations represented must be correct, and that the Mahadevas rest here upon Barakars, the Panchets and Raniganjes having died out.

Rocks concealed near Latiahar.

The beds forming the Latiahar hill are, in part at least, highly tilted, rising to an elevation of about 900 feet above the village. The thickness cannot be less here than about 700 feet.

Thickness.

At the foot of the hills south-east of Panripura I found some red shales of limited extension containing fossil plants. This was in immediate proximity to the line of fault, and it was not possible to determine to which group they belonged. They are overlaid by whitish sandstones of somewhat doubtful character, but higher on the slope are very similar red shales belonging to the Mahadevas. The fossils include species of *Glossopteris*, *Vertebraria*, *Pecopteris* and conifer seeds. It would be dangerous, under the circumstances, to refer them to any definite horizon.

Fossils.

About three miles to the west of Latiahar there is a small hill formed of these rocks, which is perhaps about 120 feet high. The beds here rest directly on Barakars. From an observation I made in the hot weather, when the jungle was bare and the lines of stratification visible in profile from a long distance off, I am inclined to believe that the beds have been faulted on the north, since it was then apparent that the lower beds of the southern scarp were cut out on the north.

Outlier west of Latiahar.

Outlier at Deobar.

The last area occupied by these rocks is in the bed of the Aurunga, at Deobar. Close to that village there is a section of some fine-grained greenish beds, which are possibly referable to the Panchets, as has been stated on a previous page; these are covered up by a set of bright-red sandstones and shales, which have some local peculiarities, but may, I think, safely be referred to the Mahadevas. Towards the base there are grits, which are not readily distinguishable from Barakars, but nothing could be stronger than the contrast afforded by the warm brick-red and purple hues of the topmost beds, to the cold, stone greys and dirty whites of the Barakar beds. In their physical characteristics these beds differ from normal Mahadevas in that they do not rise to form hills, but the Aurunga discloses long scarps, 20 to 30 feet above the bed of the river.

Lithological characteristics.

Physical characteristics.

Thickness.

They form a shallow synclinal resting with apparent conformity on a very much thinned deposit of Barakars. The total thickness was not accurately ascertained, but may perhaps be about 250 feet.

From the occurrence of ferruginous platy beds at the base of the section north of Nowagudha, which more closely resemble some of the beds of the eastern localities than do the higher members of the sequence, I think it possible that the latter belong to the very highest zone in the whole area.

CHAPTER VI.

THE HUTAR FIELD.

The remarks made on previous pages with reference to the general physical structure of this field and its surroundings render it unnecessary to preface the following stratigraphical details with any further description of them. The area of the field is 78·6 square miles. The different formations being exposed in the following proportions:—

Area.

Mahadeva Series	14·1	square miles.
Barakar Group	57·0	„ „
Talchir „	7·5	„ „
	78·6	square miles.

Section I.—Talchir Group.

At the extreme eastern end of the Hutar field rocks belonging to the Talchir group occur at the base of the hills formed of Barakars, and occupy a marginal zone of varying width and thickness. Immediately under the Kande hill the deposit consists chiefly of boulder bed, which, together with some associated shales and sandstones, attains a thickness of about 200 feet. These are directly overlaid by from 250 to 300 feet of Barakar sandstones and conglomerates. From hence, in a south-westerly direction, the marginal zone can be traced only with great difficulty owing to the covering of talus and dense vegetation.

Although I have represented it on the map as being continuous up to the Dauri river, I am doubtful about its being really so, as in several places the gneiss appeared to interrupt it, occurring up to elevations of about 100 feet on the slopes and being apparently directly covered by Barakars; but a distant view of the hill face stretching from Kande to the Dauri, obtained when the jungle had, for the most part, put on its yellow and brown tints, leads me to suppose that the Talchirs may

really be continuous. A well marked line of green trees was seen to stretch westwards, with a slope of about 5°, from a point apparently at the level of the top beds of the Talchirs in the Kande hill, down to the level of the Dauri valley. This line of green trees evidently marked the position of an impervious stratum which arrested moisture—in all probability a Talchir shale.

Dauri section.

In the Dauri section from 80 to 100 feet of Talchirs are seen resting naturally on the gneiss, a small outlying patch also occurring south of the main boundary. The bed immediately overlying the Talchirs in this section consists of a highly ferruginous sandstone which one might hesitate to include with Barakars were it not that it is associated with some small coal seams and other normal Barakar rocks.

Overlap.

Beyond the Daùri the Talchirs are traceable for about a mile, after which they are overlapped, for it does not seem probable that the boundary which strikes south-south-west past Morwaie is a faulted one.

Northern boundary.

From Kande westwards, along the northern boundary of the field, the marginal zone is traceable as a narrow strip, with perhaps one short interval, up to Ookamand. Beyond the village it spreads out suddenly, and the shales, which there thicken considerably, are spread over about half a square mile of ground. Again it narrows, and at Lohoor is overlapped completely. In this neighbourhood there is a trap dyke which traverses the metamorphics with an irregular course.

Trap dyke.

In the sections of this dyke which are exposed in the Teorohee Nadi at Kochilah and Ledgain small patches of Talchir shales are seen, which have been conserved from erosion by the protecting influence of the trap.

Thickness.

West of Lohoor the zone spreads abruptly to a width of a mile, and in the Dauri there is a considerable section in which a thickness of possibly 300 feet is exposed.

Towards the base the shales are traversed by a strong dyke of trap which in the river section is nearly 50 yards wide. Close to the top of the section there is a boulder bed, in which there are polished granite boulders up to 2 feet in diameter; besides which there are well rounded masses of a dense red quartzite, which are apparently lithologically identical with a well known form of Vindhyan rock. In Sirguja I met with a similar deposit,[a] where, since there are no Vindhyan rocks within the present existing watershed, it seemed to be necessary to invoke the agency of ice, as affording the only possible means of transport from the Sone valley. It should be stated that there are Vindhyan quartzites of precisely similar character in the Mahanadi valley, but owing to the nature of the intervening country in each case, it is perhaps more likely that the boulders were carried from the Sone.

Trap dyke.

Boulders of Vindhyan rock.

Similarly here, the Vindhyan rocks, though nearer, occur northwards, in which direction the present lines of drainage run. The supposed upheaval of the Palamow highlands, which is elsewhere discussed, would help in this case to support the view, that the boulders may have been transported southwards from the Sone valley by rivers running in an exactly opposite direction to the drainage system at present existing; but that such a fall to the south ever existed is scarcely likely, and in the Sirguja case most improbable. It may be urged, on the other hand, that Vindhyan rocks possibly existed *in situ* in both localities during the Talchir period, and were subsequently completely denuded away. In reply, it can only be said that there is not a particle of evidence to justify such an assumption.

I am anxious to give some prominence to these remarkable cases. Since, subsequently to the publication of the Sirguja instance, an early opinion of mine[b] as to the possible origin of the boulder bed has been

[a] Records, 1873, Vol. VI page 28, note.

[b] Memoirs, Geological Survey of India, Vol. vi, p. 116.

cited[a] in support of the non-glacial origin. These cases of transported Vindhyan boulders appear, however, to indicate a glacial period, quite as strongly as do the polished and striated boulders which have elsewhere been found.

Koel River section.

In the Dauri section west of the last-named locality, and at the corner of the loop bend east of Hurilong, there are pearly grey and lavender-coloured, much false-bedded sandstones, which are the highest bed of this section. They present an extraordinary resemblance to Panchet beds. West of this section the Talchirs are indistinctly traceable through Chercha up to the Koel, where they occupy a much narrowed zone, and are only seen on the western bank of the river near Hutar.

Sections west of Hutar.

Through Hutar and westwards they are found cropping out under the edge of the Barakars[b], till the vicinity of the Cheinpur road is reached south of Nowadih. Here again they are traversed by trap, and in the streams from Banulat there is a somewhat complicated section in which Talchirs, Barakars, gneiss, and then again Talchirs are met with. This section can only be explained by supposing the Talchirs and Barakars to be cut off, as is represented on the map, by the main bounding fault. A section of a similarly cut-off patch is obscurely exposed in the streams and raviney ground south of Chupatsi. The marginal zone is further traceable in a number of sections up to the Atee river near Bijka. In the Sutgurhea, the shales in contact with the gneiss are permeated by veins of pseudomorphic quartz; elsewhere along the boundary, there are indications of induration and crushing; and the distorted junction exposed in the Atee section clearly proves the existence of a fault, which is continued to the south-west past Bijka hill, where the Barakars

Boundary faulted.

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[a] Proceedings, Geological Society, London, 1877, Vol. xxxiii, p. 8.

[b] In one or two sections there seemed to be overlap of the Barakars on to the gneiss; but from the broken nature of the ground, these sections are obscure, and their exact positions difficult to determine.

and Talchirs are completely cut out, and the Mahadevas lowered to the level of the gneiss.

At the western extremity of the field a very pretty confirmation of the existence of a fault, which is otherwise pretty evident, is afforded by the occurrence of a small patch of Talchir boulder bed in the Supahi river, [at the foot of the Mahadeva scarp. The full force of this will be better appreciated by a reference to the map than by any description.

On the south boundary of the field there still remain some Talchir deposits to be noted. The first of these is at Binda, where the rocks consist chiefly of sandstones and shales underlying a small area of Barakars, which is cut off by a fault, gneiss being thrust up in the angle formed by it with the terminal fault just mentioned.

Talchirs at Binda.

Talchirs are again seen at the base of the section in the Supahi, north-west of Purro, where the lowest bed appears to graduate off into a decomposed gneiss. Hence eastwards they are more or less distinctly traceable up to the Purro stream, where a boulder bed rests naturally on the gneiss.

Talchirs at Purro.

Further east, though not exposed in the Koel section, Talchirs probably occur underneath the sandstone, as they are well developed in the streams near Mundul, where liver-coloured shales are more abundant than elsewhere. There is also a considerable boulder bed which constitutes the principal thickness in a zone which laps round the base of the Mundul range, from hence eastwards up to Hetlee, where the boundary is faulted and the Talchirs cut out.

Talchirs between Mundul and Hetlee.

SECTION 2.—BARAKAR GROUP.

At the eastern end of the field in the Kande hill station there is a thickness of about 300 feet of sandstones and conglomerates which spread thence westward, forming flat-topped ridges of a character most unlike that normally

Physical characters unusual.

exhibited by Barakars. Certain sandy ironstones and highly ferruginous slightly conglomeratic grits, which are seen in the sections of these ridges on the slopes near Ookamand and Lohoor, made me for a time suppose that these highlands were in part formed of Mahadevas. Finding, however, that these ferruginous beds in some cases occur near the bottom of the sections, being covered by typical Barakar conglomerates, I have been compelled to class all the rocks which occur above the Talchirs on the east side of the Koel as Barakars. The first regular cross-section of these beds is obtained in the Dauri, where the lowest Barakar bed at the southern end is a highly ferruginous sandstone which rests upon the Talchirs north of Saidope, as has been already indicated on a previous page when describing the Talchir section. To it succeed normal Barakar sandstones and grits, many of them, both here and in the Ghorassan river, being eroded so as to form a great variety of fantastically shaped pot-holes, which sometimes, by the breaking down of the parting walls, have coalesced to form large reservoirs, in which fish abound. In the north to south reach above the Talchirs there occur, associated with the sandstones, four seams of coal and one of carbonaceous shale, which average only from 4″ to 6″ in thickness. In the next reach there is a larger seam of about 2′ 6″; locally this dips to south-west, but that is merely due to a roll, the general dip of the rocks being northwards.

Dauri section.

Coal seams.

At the junction of the Ghorassan with the Dauri occurs the section measured by Captain Sage (*vide* p. 4). The seam, which contains some good coal[a], measures about 3′ 6″. Apparently it is exposed for some distance on the hills flanking the Ghorassan valley, since fragments from it are found in the bed of that river some distance up, though the seam is not itself exposed. The dip is 5°, to west. Soon afterwards the beds turn round to a southerly direction, and if they were more constant in character and thickness, we should find a repetition of the just described section on this, the other,

Seam.

[a] See table of assays in Economic chapter.

side of the synclinal. It is impossible, however, to recognize the foregoing section in that which follows. At the bend north-east of Badhunyah there is a seam which includes 15 inches of bright streaked but dense coal[a] dipping at 10°, to south-east. Apparently a continuation of the same seam occurs in the next reach, with dip to south-west; and in the north to south reach north of Badhunyah and south-east of Hurilong, there is a seam which measures about 40 feet horizontally, with a dip of 10°, to south, representing a thickness of nearly 8 feet. The coal is highly bituminous, the most so of any specimen examined. Its small proportion of fixed carbon (*vide* assay) would render it deficient in heating power. From its thickness, and being more easy of access than any of the others, it might prove to be of value, which the others certainly are not. In the wide hilly tract included between the Dauri and the Koel, from Hutar up to its junction with the Thatha river, I failed to find any trace of carbonaceous matter in any of the numerous streams. Close to Badhunyah, there is a sandstone which is remarkable for containing numerous marble-like concretions.

Seam.

Seam.

In the neighbourhood of Morwaie the sandstones are often highly ferruginous, and ironstones and red clays are of frequent occurrence; but the former, though furnishing an ample supply for the native furnaces, are, to the best of my belief, neither here nor anywhere else within the Hutar field in sufficient abundance to justify the belief that they could be employed profitably in the manufacture of iron on the European system, but to this subject I shall return again in the Economic chapter. South of Morwaie the Barakars are cut off by a well-marked fault. On the line of fracture associated with the fault rock I found some magnetite, partially altered into red hæmatite.

Ironstones at Morwaie.

I shall now describe the sections in the Koel and its tributaries, from north to south. First I must allude to the previous notices. Captain Sage's Burra river appears

Sections in Koel and its tributaries.

[a] I have not included the assay of this specimen in the table, as it would, being a useless coal as regards thickness, unfairly depreciate the average. The composition is, moisture 7·6, volatile 30·6, carbon 38·2, ash 23·6.

to be the same as the one called the Mungurdar by Mr. Homfray, as both speak of the near proximity of Hutar. Unfortunately I find that when on the spot I omitted to enquire the names of the two branches of the river at Hutar. The true Mungurdar river, however, joins the Koel nearly four miles north of the coal-field at Hutar, and to the best of my belief does not traverse any outlying patch of measures, but I have not examined its course throughout. What river Mr. Homfray indicates by the name Barwellia, which he speaks of as 'running to the eastward,' *i.e.*, coming from the west, unless it be the Supahi, I do not know. I have already commented on some other of Mr. Homfray's statements.

Previous notices.

In the Koel, Talchirs are seen under the west bank up to within a short distance of the Hutar river. Barakars then supervene, and the following section is found in the southern, Nowadih, branch of the river close to the lower tolehs of the village. Resting on sandstone there is a seam about 5 feet thick, of which the bottom, 1 foot, consists of coal, dip 15°, to south. Above this there are shales very like Talchirs in lithological characters, followed by an irregular seam about 10 feet thick, including 1 foot of bad coal at top and 1′ 4″ of good coal at base (*vide* assay). This seam is traceable westwards for about a mile. Although it varies somewhat in character, the thickness of the included coal remains pretty constant. The Nowadih hill to the south is composed of sandstones and conglomerates, with which there are some ironstones, which are smelted by the Aguriahs of several neighbouring hamlets. This neighbourhood, as a site of iron manufacture, was mentioned by Captain Sage in 1830, and from the great abundance of slag, it is evident that there have been furnaces here for a long period.

Seams at Hutar.

Ironstones at Nowadih.

From the mouth of the Hutar river to that of the Supahi, the Koel exhibits a broken section of sandstones with southerly dip. In the Supahi from its mouth up to the point where it leaves the Doothoo hills, which are formed of Mahadevas, there is a more or less interrupted section of grits, sandstones, and conglomerates, with dips of from 10° to 15°, to south.

Supahi section.

At a short distance on either side of the Daltonganj road-crossing, there are carbonaceous shales, those on the west including 6″ of coal. From the occurrence in other sections of certain peculiar beds towards the top, it at one time seemed probable that these were representatives of a group or sub-group between the true Barakars and the Mahadevas in the portion of the Hutar field which lies west of the Koel. In this particular section, however, the beds seem to be normal Barakars. Owing to the steadiness of the dip, this section and that of the neighbouring Hurtah river afford unusual opportunities for measuring the thickness of beds intervening between the top of the Talchirs and the bottom of the Mahadevas. Estimating the average dip at 12° and the horizontal distance 2½ miles, the thickness would be about 2,750 feet. This is the maximum thickness at the centre of the basin, and it is much in excess of that found elsewhere.

Abnormal top beds.

Thickness.

The most important of the Supahi tributaries is the one which rises in the Hurtah or Hudur hill, and bears the same name. The section which commences near Titaro (Toleh of map), a small Aguriah hamlet, is as follows:—

Section in Hurtah.

Talchir shales.

Grits and shales of uncertain thickness.

1. Flaggy shales, rolling, say 800′ at 5° =		70′ 0″
2. Sandstones, 400′ at 5° =		34′ 9″
3. Sandstone and sandy shale, part concealed, 220′ at 10° =		38′ 2″
4. *Seam*, dip 10°		3′ 0″
5. Sandstones		17′ 4″
6. *Seam*—		
a. Stony carbonaceous shale	2′ 2″	
b. Coal	1′ 2″	
c. Carbonaceous shale	0′ 10″	
d. Coal	1′ 0″	
		5′ 2″
7. Sandstones and grit, 27′ at 15° =		6′ 10″
8. *Coal*		0′ 2″
9. Grit		5′ 0″

Here there is a slip and repetition of section—

Seam—		This illustrates the rapid changes in character of beds which so frequently take place.
Coal, seen	1′ 6″	
Sandstones	17′ 5″	
Coal	0′ 2″	
Grit	10′ 0″	

10. Interval, 50' at 10° = ...	8' 8"
11. Sandstones, 32' at 10° = ...	5' 6"
12. Sandstone with irregular band of coal, mostly stony .	3' 6"
13. Grit with scattered pebbles, 280' at 8° = ...	38' 10"
14. Interval, in which some thin carbonaceous layers occur, 50' at 15° = ...	12' 10"
15. Sandstones, 92' at 10° = ...	5' 6"
16. *Coal*	0' 8"
17. Sandstones, 18' at 10° = ...	3' 1"
18. *Coal*	0' 4"
19. Carbonaceous shales, with thin layers of coal and sandstones, 165' at 120° = ...	34' 2"
20. Grits, 95' at 15° = ...	24' 7"
21. Carbonaceous shales, layers of *coal* 6" thick towards top and bottom, 60' at 12° = ...	12' 5"
[Beds here distorted and repeated.]	
22. Sandstones and grit	8' 0"
23. Interval, in which some carbonaceous shales are seen to occur, 50' at 10 = ...	8' 8"
24. Sandstones and grits, including 4" band of *coal* at centre, 110' at 10° = ...	19' 0"
25. *Coal*, shaly-impure.	
26. Thin sandstones, and carbonaceous shales, 150' at 8° = .	20' 8"
27. Sandstones and grits, with irregular nests and layers of carbonaceous matter, 150' at 8° = ...	20' 0"
28. Sandy and carbonaceous shales, 50' at 10° = . . .	8' 7"
29. Carbonaceous sandstone	3' 6"
30. *Seam*—	
Appears to consist mainly of a dense, rather dull coal, but portions with bright layers, flaky towards base, dip 8° .	8' 0"
31. Sandstones 100' at 8° = ...	13' 10"
32. *Seam*—	
Carbonaceous shale . . . . 0' 4"	
Shaly *coal* . . . . . 2' 0"	2' 4"
33. Sandstones and grits cut into gorge, 300' at 10° = . .	52' 2"
34. *Seam*—	
Coal with sandstone, possibly ⅓rd coal, 50' at 8° = .	6' 10"
35. Sandstones and grits with conglomerates	60' 0"
36. *Seam*—	
Quality inferior, but part concealed, 100' at 10° . .	17' 5"

Beyond this, up to the junction with Supahi, there are no more seams exposed. The rocks are grits and conglomerates with rare carbonaceous layers. Among the above the seam of real value appears to be No. 30. The average composition of two specimens is good,[a] and the thickness and dip both favourable to working.

Section in Chupatsi river.

To the north and north-west of this line of section small patches of Barakars have been cut out by the main bounding fault. The first is tolerably clearly seen, but the second seems to be complicated by the occurrence of some small slips parallel to the main bounding fault. In the Chupatsi stream there is a section of the carbonaceous zone shewing a diminution in the number and thickness of the seams. There are here in all about six, the coal being in bands from 6″ up to 2′ 6″ in thickness.

Section in Satghoria river.

In the Satghoria river there is another cross-section of this zone. The highest seam varies, within the limits of the width of the stream, from 1′ to nearly 4′. Below it come a series of seams whose average thicknesses are as follows—3′, 2′, 1′, 1′, 1′. These occur in alternation with massive beds of grits and sandstones of from 12 to 20 feet in thickness. There is no workable thickness of coal exposed in either of these last sections. In the almost entire absence of shales, they contrast with the section seen near Hutar, but very closely resemble the sections near Purro on the south of the field which will be described further on.

Section in Atee.

The last tributary of the Supahi in this part of the field whose section remains to be described, is the Atee. At the point south-west of Bijka, where the Atee river leaves the hills, there are Barakar grits and pebble beds with a narrow border of Talchirs. The dips fall rapidly from 50° to 20°. The lowest beds are much indurated and crushed by faulting, which is further indicated by the presence of a ridge of fault rock which strikes hence towards the Bijka hill. Among the broken fragments close to the line of fracture there are some pieces of coal which are derived from

[a] *Vide* Table of Assays.

a seam now concealed. In the river section south-west of the village there are, resting on the typical Barakar grits and pebble beds, some fine sandy shales and green silty Talchir-like clays which, taken in connection with other like exposures, suggested the possibility, as I have already stated, of there being in this field a group of beds separ-

Talchir-like beds.

able alike from Barakars and Mahadevas. This view I have been obliged to relinquish. In the remainder of the Atee section, from Bijka up to the junction with the Supahi, these green beds occur with the grits, and no coal seams are exposed.

Section in Koel river.

In the Koel river, from the mouth of the Supahi to the mouth of the Thatha, sandstones, &c., with south dip are occasionally exposed.

Section in Thatha river.

In the Thatha river there are several seams of carbonaceous shale with coaly layers, but their position is uncertain, owing to the inaccurate plotting of the stream. Beyond the village the section is interrupted by the already alluded to Morwaie fault, in conjuction with which is the hot spring already described.

Seam.

Further east a seam of about 1′ 4″ of coal is seen twice in the bed of the river, being bent by the fault into a synclinal.

Section in Koel river.

The section in the Koel, from the mouth of the Thatha to the Mondul stream, again exposes nothing noteworthy till near the latter spot, when a coal seam is partially exposed under the eastern bank. This is the only

Seam.

seam uncovered in the whole course of the Koel. The coal is much decomposed, and as only three feet is exposed, it is not possible to say whether the seam is of value; the dip is 10°, rising to 15°. The long hog-backed ridge which strikes eastward from this is made up of grits and conglomerates, and possibly coincides with a branching line of fracture, since fragments of fault rock are found in some abundance on the slopes. Half a mile to

East and west fault.

the north, fault rock, which marks the position of the Morwaie east and west fault, is seen

in situ. In its neighbourhood the Barakar grits are intensely disturbed and indurated. West of the Koel, on the same line of strike, runs the foot of the Mahadeva scarp. I have already stated the possibility of the Mahadevas being faulted and a portion of the Barakars cut out here.

Section in Mundul river.

In the Mundul river the section exposes a number of thin seams of coal and carbonaceous shale alternating with sandstones. These seams are too thin to be of value.

Section in Purro river.

In the stream which runs through Purro, west of the road, there is a considerable section of sandstones with some carbonaceous shales, and four seams containing from 6 inches to 1 foot of coal. The coal is of good quality, but nowhere sufficiently thick to be of value.

Other sections in Supahi.

The Supahi and its tributaries south of the Doothoo hills afford several more sections. In the former, before it enters the hills, there is a narrow margin of Talchirs, above which there are coarse Barakar grits dipping at 25°, to north-west. Above these there are somewhat conglomeratic grits, which resemble certain beds occupying the same relative position in the Aurunga field. The next rocks seen are rusty Mahadeva sandstones dipping 15°, to north. It is uncertain whether they are superposed or are separated by a fault.

Section in Ledkee river.

In the Ledkee stream, which joins the Supahi near its entrance to the hills, there are rocks resembling the highest beds seen in the Atee at Bijka, and with them some others whose lithological affinities are certainly not with ordinary Barakars. Besides the green beds, there are grits which include angular fragments of gneiss, &c., and also fine calcareous sandstones.

Difficulty in separating top beds.

Any attempt to separate these rocks as constituting a distinct group is beset with difficulties, since there are not a few sections in which the Mahadevas

directly overlie normal Barakars. So that were the former really distinct, there would be a good deal of unconformity which would have to be explained away. Regarding them as being merely local varieties of Barakars would get over the difficulty of their not appearing in some sections. A dotted line on the map indicates the limits within which these rocks have been observed.

Section in Supahi river at Binda.

Still another section of Barakars is afforded by the Supahi where it traverses a small area of those rocks which are cut off by a fault at the extreme west end of the field. The following is the measured section in the Supahi at Binda from north to south, descending, dip 10°, to north :—

Gneiss faulted.

1.	Interval . . . 33' } at 10° =	5' 9"
2.	Grits, part concealed, 28' } at 10° =	4' 9"
3.	*Seam* (*vide* assay) 25' } at 10° =	4' 4"
4.	Sandstone	4' 0"
5.	*Seam*—	
	Shale . . 0' 4"	
	Coal . . 1' 0"	1' 4"
6.	Sandstone	3' 0"
7.	*Seam*, very indistinct	2' 0"
8.	Sandstone, part concealed, 50' at 12° = . . .	10' 5"
9.	*Seam* (*vide* assay), 53' at 15° = ...	13' 8"
10.	Felspathic grit, 50' at 15° = ...	12' 10"
11.	Carbonaceous shale, passing into grey sandstones and grits, 33' at 10° = ...	5' 9"
12.	Thin sandstones, with some thin coaly layers, 200' at 10°	34' 9"
13.	Interval, 100' at 10° = ...	17' 6"
14.	Grits = ...	12' 0"

Fine-grained yellow sandstones—Talchirs.

It will be seen, on reference to the table of assays, that seams Nos. 3 and 9 contain coal of very good quality. On the other hand, a reference to the map will shew that, owing to the fault having brought up the gneiss so close to the outcrop, the quantity is very limited

...ndence of Capt. T. Waterhouse Surveyor Generals Office, Calcutta. July 1878.

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indeed. Perhaps this is the less to be regretted, since the locality is too difficult of access ever to be of much importance.

SECTION 3.—MAHADEVA SERIES.

Rocks of this series, though largely developed west of the Koel, are not now represented by any deposits in those parts of the Hutar field which lie to the east of that river. Their general aspect, throughout the elevated tract which extends from the west bank of the Koel, where they rest upon a great thickness of Barakars, to the end of the field, where they are cut off by a fault, corresponds closely with the appearance of rocks of the same age in the Karanpura fields. The lithological characters, too, are identical.

Possible unconformity.

Owing to the difference in the thickness of the sections of the Barakars which are found on the north and south, it is possible that the Mahadevas may have been let down by a fault, a portion of the Barakars having been cut out. This appearance may, however, be attributable either to original irregularity of deposit of the Barakars, or to unconformable superposition, the existence of which is rendered probable by the non-representation of the Raniganj and Panchet groups in this area.

Section in Supahi river.

The most complete section of these rocks is afforded by the Supahi, which traverses a deeply cut gorge through the mass of hills north of Purro. At the mouth of the gorge the rusty-looking grits and sandstones dip 15°, to north. At about the centre of the gorge the beds flatten, and the water runs between steep walls, 30 feet high, in which the rugged and honey-combed edges of the beds are exposed. Pot-holes abound, and contribute not a little to produce a striking effect. This is especially the case at the waterfall which is fed by the Hulka stream on the west.

Scenery.

The scene is one of peculiar beauty, not that there is, in the dry season at least, a copious fall, but because the water trickles into vast pot-holes, and flows over the edges of these natural basins, the innermost recesses of which can be

viewed through the pellucid waters. In the well-shaded Hulka valley the grotesque forms of the eroded sandstones and the brilliant hues of the vegetation, which includes ferns, a small *Arum*, *Drosera*, grasses, mosses, &c., combine to make up a scene which is most refreshing in March or April after the black, scorched, and dusty jungles outside.

Towards the northern end of the gorge the beds are tilted again, dipping west of south at an angle of 8°.

Bijka hill.

In the Bijka hill (2,479 feet) these rocks attain their maximum development, though it is difficult to estimate the thickness exactly. The summit of the hill is about 1,300 feet above the village. The inclination of the beds is from one point of view only 5°. The northern face of the hill is backed by a strong ridge of fault rock, which marks the position of the main boundary fault. In part, then, the elevation may be due to tilted Barakars at the base, but I think it probable that the thickness of Mahadevas cannot be far short of 1,000 feet.

Cross-fault.

Towards the top the sandstones present a somewhat vitreous appearance, being not unlike some forms of Vindhyan rocks. Beyond the Bijka hill the older groups are cut out completely, faulted junctions between the edges of the gneiss and the Mahadevas being exposed on the slopes. Before the Supahi is reached, a cross-fault limits the further extension. It is probable that a much thinned out deposit of Barakars has been here cut off. That the Barakars were dying out here is evidenced by the fact that only two miles further west the Mahadevas, at a level perhaps 200 feet higher, rest directly on the gneiss. A small patch of Talchir boulder beds at the foot of the scarp, and the Barakar and Talchir beds at Binda, are the sole remnants of the lower groups which are left to indicate former extension.

The outlier which in the Sitwa hill rests on a base of gneiss spreads westwards through the level country near Budhunya. The

southern and western boundaries appear to be continuations of the Bijka and Binda faults, which would intersect one another near Kajuri.

Sitwa hill outlier.

I have on the map indicated the probability of the Bijka fault being continued to Tatapani, but am as yet by no means certain that it is so.

The lithological characters of the rocks forming this outlier are normal, *i. e.*, identical with those of the adjoining main area.

CHAPTER VII.

ECONOMIC RESOUCES.

SECTION 1.—COAL.

In the accompanying table I have given the results of my assays of the specimens of coal which I collected in the three fields. These results are completely confirmatory of the opinions which I formed in the field as to the relative merits of the seams. The coal of Daltonganj has the advantage of having been opened up, but I doubt if this is sufficient to account for the difference in the percentages between it and the Aurunga coal, and this is the more probable, since the Hutar coal has yielded such good results.

Comparative merits of the coal.

The Daltonganj Field.

No doubt whatever exists as to the excellent quality of the coal in this field. It has been proved, both by assays and actual experiments, to have great heating power, and to be admirably adapted to steam purposes.

Mr. Hughes' estimate of 11,600,000 tons as the amount of available coal is, as far as I have had opportunities of forming an opinion, a safe minimum. Although there is good reason for believing that the coal of this area, as in the Aurunga field, occurs in basins of limited extent, that is to say, that it is not of equal extent with the coal-measures, still there is a fair probability that there may be basins of coal in the portion of the field to the south-east where the rocks are much concealed by superficial deposits. This can only be ascertained by systematically conducted borings. The Singra seams too, which are not included in Mr. Hughes' estimate, contain coal of so good a quality that it might very probably be worked profitably by open quarries for some years.[a] In any case, the 11,600,000 tons would last for 50 years, at the

[a] The Singra coal was being used for lime-burning at the time of my visit.

rate of 200,000 tons per annum, which is the amount that the projected line and canal would be capable of carrying, according to Colonel Haig.

The average composition of the four specimens, which were in each case taken from the coal actually stacked for consumption, amounts to—

Moisture 3·45, volatile 21·05, carbon 64·8, ash 10·7.

The Aurunga Field.

The coal which occurs in the rocks of the Raniganj group is of too unimportant a character, whether as regards quality or thickness to be considered as affecting the question of the amount economically available in this area.

Coal inferior in quality.

The improbability of this field containing a large supply of really good coal is very great. The appearance of the seams, and the result of the assays, both point to this conclusion. At the same time, it should be remembered that there is not a single fresh and clear section of the rocks, and that the coal has never been quarried to the smallest extent. Of coals with an average composition similar to that given in the accompanying tables, I think the following quantities would be available:—

	Tons.
Rajbar seams	12,000,000
Toobed "	3,000,000
Jugguldugga "	5,000,000
TOTAL	20,000,000

Minor localities not included.

It is unnecessary to include here any of the other localities, where I have indicated the presence of coal in the previous pages, and on the map. It is possible that borings may prove the seam in the outlier at Dudhoria, or those on the south of the field in the Gowa section, to have some value. But dealing only with the facts which are available, they must be omitted from consideration at present. The obviously bad quality, or limited extent of other seams, as at Hoochloo and north of Manjar, have been alluded to; and these also are therefore not included.

Unless very much better qualities of coal exist in the Aurunga field than the very best seen by me, it is manifestly impossible that iron can be manufactured on the spot.

Coal not suitable for iron smelting.

Hutar Field.

I have already pointed out that the coal-measure rocks of this area present many striking differences from those of the Aurunga field. To this rule the coal is no exception, as will at once be apparent by a comparison of the average assays in the accompanying table. From the Daltonganj coal that of Hutar differs in containing a notably smaller proportion (7·15 per cent.) of fixed carbon, and would, therefore, have a less heating power. The proportion of ash, 10·7 per cent., is the same in both. On the whole, however, the Hutar coal is quite equal to the average of Indian coals, so far as regards quality. Much uncertainty must attach to any estimate of quantity. Only three seams of good quality, containing a thickness which could be worked with profit, are known to exist; these are as follows:—

Lithological characters peculiar.

Coal compared with that of Daltonganj.

Dauri river section, south-east of Hurilong . . .	8′ 0″	seam.
Hurtah river, at Toleh	8′ 0″	„
Supahi river, at Binda	13′ 8″	„

It is possible that the Dauri river and Hurtah river coals may be continuous right across, but since there is no intervening section exposed in the Koel, or elsewhere, it would be most dangerous to base any calculation on the mere supposition. In fact, the lateral extension of both these seams being quite unknown, it would be utterly futile to attempt any estimate of the number of millions of tons they may contain.

No definite estimate of quantity possible.

That the 13′ 3″ seam at Binda on the Supahi contains but a very small quantity of coal is as certain as anything can be, the fault along which the gneiss has been thrust up occurring within a few feet of the outcrop.

I do not at all despair of this field being found to contain workable seams of value, but the facts at present available do not justify any confident expression of opinion that such will certainly prove to be the case.

Assays of Coals from the Palamow Coal-fields.

Field	Locality.	Formation.	Moisture.	Volatile.	Carbon.	Ash.	Character of Ash.	Appearance of Coal.	Remarks.
AURUNGA COAL FIELD.	Subano river, 1' 6" seam	Raniganj Group	5·	33·8	36·2	25·	Dark grey	Cubical fracture; bright layers.	
	Rajbar, No. 21 of section	Barakar „	8·4	28·6	33·	30·	„	Laminated bright layers.	
	„ „ 27 of „	„ „	7·	26·2	38·4	28·4	Grey	Earthy-looking, with irregular bright layers.	
	Bagh-Digwa river, 1' 6" seam	„ „	7·2	32·	45·	15·8	White	Laminated.	
	Stream west of Jornean, loose fragments 8" thick.	„ „	6·4	26·6	33·6	33·4	Reddish	Laminated, contains altered pyrites (red hæmatite).	
	Toobed Section, No. 5	„ „	6·2	28·6	30·6	34·6	Dark-grey	Very dull and earthy-looking.	
	„ „ „ 11	„ „	6·8	29·	38·6	25·6	Reddish-grey	Laminated; contains altered pyrites.	
			47·0	204·8	255·4	192·8			
	Average for Aurunga Field	......	6·7	29·2	36·5	27·5			
HUTAR-COAL FIELD.	Danai river, 3' 6" seam	Barakar Group	6·2	30·6	53·	10·2	Reddish-grey	Somewhat homogeneous, but streaked with bright layers.	
	„ „ 8' 0" „	„ „	7·6	39·	43·6	9·8	„ lighter	Ditto ditto.	
	Hutar „ 1' 4" „	„ „	7·4	17·2	65·4	10·	Grey	Ditto ditto; cubical fracture.	This seam is difficult of access.
	Hurtah „ No. 30 a 8'	„ „	4·	19·8	58·	18·2	Brick-red	Ditto ditto.	
	„ „ „ 30 b 5'	„ „	8·6	26·	57·	8·4	Brownish-grey	Very bright and very dull layers alternating	This is the most valuable seam known to exist in the Hutar field; the average composition of the two specimens is m. 6·3, v. 22·9, c. 57·5, a. 13·3.
	Binda No. 9 of section 13' 8"	„ „	3·8	34·	53·8	8·4	Reddish-grey	Dull; lamination obscure.	This seam is of too limited extent to be of much value.
	„ „ 3 „ 4' 4"	„ „	5·6	36·	50·6	7·8	„	Bright and dull layers alternating	
	Supahi river, loose block	„ „	4·4	21·4	61·4	12·8	Grey	Laminated: bright layers predominate.	Ditto ditto.
			47·6	234·0	442·8	85·6			
	Average for Hurta Field	......	5·95	28·	„	10·7			
DALTONGANJ COAL-FIELD.	a Pandua Quarry	Barakar Group	2·	22·	67·8	8·2	Brownish-grey	Laminated; very bright looking	Had been stacked for two years.
	b „ „	„ „	1·8	21·	66·4	10·8	Grey	Similar; but lamnation finer	
	Singra 4'·6" seam	„ „	8·4	19·8	62·4	9·4	Dark-grey	Similar, stained with red hæmatite.	
	Specimen from Palamow forwarded by Mr. Hope.[a]	„ „	1·6	21·4	62·5	14·5	Reddish.		
			13·8	84·2	259·1	42·9			
	Average for Daltonganj Field	......	3·45	21·05	64·8	10·7			

N.B.—None of the above are coking coals.

[a] Assayed by Mr. Mallet.

SECTION 2.—IRON.

The iron ores found in Palamow admit of a triple classification, founded both on their mode of origin, their geological position, and on their chemical composition. So arranged they stand as follows :—

Magnetite	*a.* Pure magnetic ore . *b.* More or less decomposed and altered.	These occur either in bands and lodes in hornblendic rocks, or as detached crystals in granite veins.	Crystalline and metamorphic rocks.
Siderite and hæmatite .	*a.* Carbonate or black band. *b.* Limonite or brownish hæmatite. *c.* Red hæmatite . .	*a.* Bedded shales. *b.* Concretionary masses in sandstones.	Coal measures, Barakar group.
Red and brown hæmatite .	Bands of one or other of these ores occur in the laterite which cap the plateaux above 3,000 feet in elevation.	. . .	Laterite.

Magnetite.

From time to time specimens of pure or nearly pure magnetic ore have been picked up by district officers and travellers, or brought in by natives to Dehree and elsewhere from the Palamow sub-division. Such specimens have, on being assayed, naturally yielded most favourable results. Occasionally the localities whence these ores have been brought have been described, on native or other irresponsible testimony, as containing *inexhaustible* supplies of similar ore. But what has perhaps more than anything else tended to give rise to misconception has been the fact

that descriptions of ores of quite distinct character[a] have been coupled with the assays of the magnetite, and thus conclusions have been drawn by combining the abundance of the former with the richness of the latter, which are not warranted by the real facts of the case.

That within the limits of the sub-division, inexhaustible deposits of magnetite may exist is quite possible. I know of places in the south-east of the Manbhoom District[b] where such is the case; and many of the chief deposits of magnetite throughout India occur in rocks of the same geological age as those which form the greater part of Palamow.

My observations were limited to mere superficial examination of the ground, there being no time for opening up trenches. I believe, however, that I have seen all the principal sources of iron within the tract under review, and am compelled to regard it as being most improbable that any considerable deposit exists clearly exposed. Any very remarkable deposit other than those about to be described would almost certainly have been brought to notice by the natives. There is ample consolation, however, afforded by the fact that, although the ores which have been mainly instrumental in attracting attention to Palamow are not of great promise themselves, there are others whose quality and abundance are of a most satisfactory nature. Before describing these latter, it will be necessary to give a detailed account of observations made on the several deposits of magnetite which have been visited. The following is a list of the villages in whose vicinity these deposits respectively occur:—

Rajhara[c] . .	Tuppeh[d]	Bari.
Lunkha . .	„	„
Kopeh, (south-west).	„	„
„ (south-east).	„	„
Satbarwah . .	„	„

[a] e. g., the laterite of Neturhat.

[b] These are in the sub-metamorphic rocks.

[c] This is quite a distinct locality from Rajhara in the Daltonganj field. It is situated east of the Mylee river, and northwards from Satbarwah.

[d] Tuppeh is a local term corresponding, I believe, to parganah.

Hosir . . .	Tuppeh	Bari.
Monodag . . .	"	Toree.
Hirhun or Harhunj .	"	"
Kurahi . . .	"	Doothoo.
Adur . . .	"	"
Morwaie . . .	"	Doorjag.
Kotam . . .	"	Semah.

Rajhara.—I visited this locality in company with Mr. L. R. Forbes, Assistant Commissioner, who had previously been there, and had brought from thence some specimens of very pure magnetite. In a stream about ⅔rds of a mile north-west of the village, for a distance of about 50 yards, flat, but weathered fragments of magnetite occur rather abundantly scattered through the gravel. In the bank of the stream there is an imperfect section of the rocks, which consist of hornblendic and granitic gneisses with granite and quartz veins. The strike of these beds is irregular, but the prevailing direction is from west-north-west to east-south-east, and the dip vertical. We failed to find any sign of the ore *in situ*, though it appeared to occur in so limited a section of the stream bed. The legitimate conclusion seemed to be that the fragments were the sole remnant of a nest or band of ore which had been eroded from its environment of hornblendic gneiss.

Leaving the stream and crossing some raviney broken ground westwards towards a small hill of hornblendic gneiss, similar fragments were found here and there at various levels through the detrital soil, from the beds of the ravines up to the top of the lower detrital slope of the hill, but there were neither fragments nor ore *in situ* discernible on the hill itself.

I am, under the circumstances, inclined to believe that these fragments now exposed in the channels are proximately derived from the re-assortment of old detritus and not directly from any exposed vein or layer.[a] The toughness and power of resisting disintegration, together with the high specific gravity, would sufficiently account for the survival of the

[a] Magnetite occurs sometimes in nests or veins, sometimes in apparent beds which underlie with the metamorphic rocks.

fragments of ore long after the other materials had been washed away; these fragments might conceivably be a remnant left after the erosion of many hundreds of feet of rock.

From the tabular character of most of the fragments, which are rarely more than two inches thick and more commonly only one and-a-half, it seems probable that the layer was a thin one; and it is further probable from the dips of the rocks and of the veins of quartz and granite that its underlie was steep.

However promising this spread of fragments along a line of strike may appear to casual observation, it is, under the circumstances, not such as to justify a belief in the existence of an inexhaustible supply, though such may exist hidden away under the surface.

Lunkha.—In a small ridge north of the village of Lunkha there is a considerable abundance of fragments of magnetite. One irregular block measured upwards of half a cubic foot in content.

There being no higher ground in the immediate vicinity, these fragments must necessarily mark the position of the original outcrop, which extends at least as far westwards as the Semah road, but I did not see any sign of its being exposed in the section in the bed of the Aurunga. This ore is very pure magnetite. Should occasion arise, it would not be a very arduous undertaking to sink a few trenches at right angles to the strike. These could not fail to find the vein, if any of it remains to be mined.

Kopeh, south-west.—One mile to the south-west of Kopeh, I found, in the ravines, a large rounded fragment of magnetite about the size of a man's head, which had probably been derived from a nest in the hornblendic rocks occurring in that neighbourhood. None was found *in situ.*

Kopeh, south-east.—The iron-workers at Kopeh, though living close to the Lunkha ore, do not make any use of it, and when I shewed them a very fine specimen of magnetite, said that it would not answer for their purposes.

The ore they do use consists of small semi-decomposed-crystals of magnetite derived from disintegrated granite veins, and laboriously

sifted from the sand accumulated in ravines near the Ledee stream south of the Aurunga. This ore has to be ground between stones to a fine powder before being smelted; hence, perhaps, the name *bali*, (sand).

Satbarwah.—To the south-west of Satbarwah, near Rubdah, on the slope of a small hill, there are traces of ore. These are mostly of decomposed and altered magnetite. Although a road crossing the hill gives a complete section of the hornblendic gneisses and granite of which it is formed, I could find no nest or bed of ore. This ore is not used at present, there being no Aguriahs in the vicinity.

Hosir.—The ore used at Hosir seemed to be similar in character and origin to that south-east of Kopeh. I did not, however, visit the locality whence it was brought. The iron-smelters at Gowa employ, I believe, the same ore.

Monodag.—In the stream south-west of Monodag, which is to the north north-east of Mooroop, there are some bands of magnetite seen in the gneiss. These are not of sufficient thickness to be of much importance.

Hirhun or Hurhunj.—In a stream near this village, when marching up to the Daltonganj field with Mr. Bauerman in 1873, we found a few small fragments of magnetite. There was no evidence of the existence of a large deposit.

Kurahi.—This locality is situated in the centre of the extensive group of hills south of Cheinpur, being about four miles south of Chandoo. The ore is used by the smelters of Chorhut.

Whether there are other localities besides the one I was taken to I cannot say, but all that the people knew of was a shallow hole in the middle of a standing crop of râhar dhâl, and which penetrated into an amorphous mass of decomposed ore. A large fragment of undecomposed ore had been thrown on one side, as being apparently unsuited for the smelter's purpose. In the cleared spaces on either side of the field, where the rocks were partly exposed, I could find no traces of the extension of the deposit, which is, therefore, probably a mere nest in the hornblendic gneiss and of limited extent.

Adur.—Mr. D. Smith describes some ore which he examined about two miles north of Chorhut in the vicinity of Adur, in the following words: it is "a very partial deposit of magnetic ore of the very richest quality, but so limited in quantity as to be of no importance."

Morwaie.—On the faulted boundary of the Hutar coal-field south of Morwaie there is, in conjunction with some fault rock, an outcrop of magnetite much altered and decomposed, principally into red hæmatite. It is imperfectly exposed, and I cannot speak definitely as to quantity; but I failed to meet with it again in any of the cross-sections of the line of faulted contact.

Kotam.—Near the junction of the Kaliburna river with the Koel and also close to Kotam, small fragments of magnetite, some superficially altered to brown and some to red hæmatite, are found scattered about with fragments of vein quartz. Save at Chipars, there are, I believe, no smelters in the Semah valley at present. Several families of Aguriahs have had to give up their trade owing to forest conservancy having put a stop to the manufacture of charcoal.

From the foregoing it will be seen, with reference to the commercial aspect of the question, that two conditions, which are of primary importance, 1*st*, the existence of an abundance of ore—a practically inexhaustible supply—and 2*nd*, the possibility of working such an ore by a simple system of mining, are not distinctly afforded by any of the abovenamed deposits; and, in the absence of such evidence, it will perhaps be, in the long run, more profitable to direct attention rather to those ores which, though less rich, are abundant and can be raised without any difficulty whatever.

The magnetites, if found near the line of transport, would always be of value for 'fettling' and, so far as the supply would go, for mixing with the less rich ores.

Carbonates and carbonates altered into hæmatites.

This heading has been adopted, as it is most probable that, notwithstanding the present rareness of carbonates, most, if not all, of the

ores[a] about to be described originally existed as such. At present we find that the ores commonly associated with coal-measures consist of brown or red hæmatites, or mixtures of both.

According to Mr. Hughes' report on the Daltonganj-field, it would seem that within its limits there are no deposits of iron ore of importance. In certain parts of the Daltonganj field shaly and concretionary fragments of ore may be seen strewing the surface. And from the traces of slags it is apparent that iron has been manufactured from these ores. Such accumulations are, however, quite consistent with a great poverty of the deposit; and all experience shews that much reliance should not be placed on such apparent evidence of abundance.

In the Hutar field, as has been already indicated in the account of the coal-measures of that area, there are numerous deposits of iron-stones, but since it is believed that none of these deposits are sufficiently extensive to justify the hope that the establishment there of iron works would have a favourable result, it will be unnecessary in this Economic account to recapitulate the details regarding that area.

In the Aurunga field and its neighbourhood, however, there is an undoubted abundance of good ore which is most favourably situated as regards limestone flux, if not as regards fuel.

Aurunga field.—Since from the inferior quality of the coal it is not likely that the iron ores would ever be smelted on the spot, the Rajbar ores are less conveniently situated than those which are found in the outlier near Chiru. The latter, as has been shewn, are sufficiently abundant to meet all possible requirements, and their quality is shewn in the assays given in the accompanying table. A very important point regarding these ores too is, that since they occur near the surface and could be easily worked, no expensive mining establishment need be maintained. The same remark applies to the limestone. This would not be the case with the magnetite ores, supposing them even to be vastly more abundant

[a] Possibly some of the concretionary masses were never carbonates.

than they appear to be. There remains only to be discussed the means of conveyance of these ores to the fuel.

The question of the expediency of constructing a line of railway to connect the canals with the Palamow coal-fields being under consideration and report by the Public Works Department, it is unnecessary for me to do more than add a few lines on the subject, and this the more particularly, as I have no personal knowledge of the comparative merits of the different routes which have been proposed.

From what has gone before, it will be apparent that, in so far as I have examined the country, I am committed to the opinion that the only localities where there are iron ores and limestone suitable in all respects for iron manufacture are situated in the Aurunga field and its outlier; and that the coal which is most likely to be suitable for smelting these ores and for steam purposes is that which is found in the Daltonganj field.

The connection of the Daltonganj field with the East Indian line is then the most important and primary part of the project, and that this should be effected by means of a line from Dehree and thence onwards by the canals seems a necessary conclusion. But it has been proposed to extend the line from Gya to the coal-field *viâ* the Mohur valley. Into the discussion of the comparative merits of these schemes I am unable to enter, and it only remains for me to point out that if iron is to be made, the ores and limestones of the Aurunga field will have to be carried to the Daltonganj coal, or *vice versâ*. Probably the former would be the less expensive plan, as the coal and iron would have to be carried to and fro respectively, while in the former, the ore and lime would simply have to be drawn from the Aurunga field and smelted at the coal mines.

Distance of iron from good coal.

Roughly speaking, the distance of the Aurunga field from the Daltonganj coal mines *viâ* the valley of the Amanut would be about 50 miles. The probability of its being possible to carry the ore with profit for this distance by a specially

constructed line, or by any other means of transport, seems to be somewhat slender, but I must leave it to others to decide this question. It depends upon the alignment adopted for the Gya-Daltonganj line whether some reduction would not be possible in the length required for the special branch to the ores.

Laterite.

The position of the excellent ores which are found at an elevation of 3,600 feet in the laterite of the Neturhat plateau renders them absolutely valueless from an economic point of view. A glance at the accompanying general map will be sufficient to shew the nature of the physical difficulties in the country surrounding the Tuppeh Semah in which the Neturhat plateau is situated.

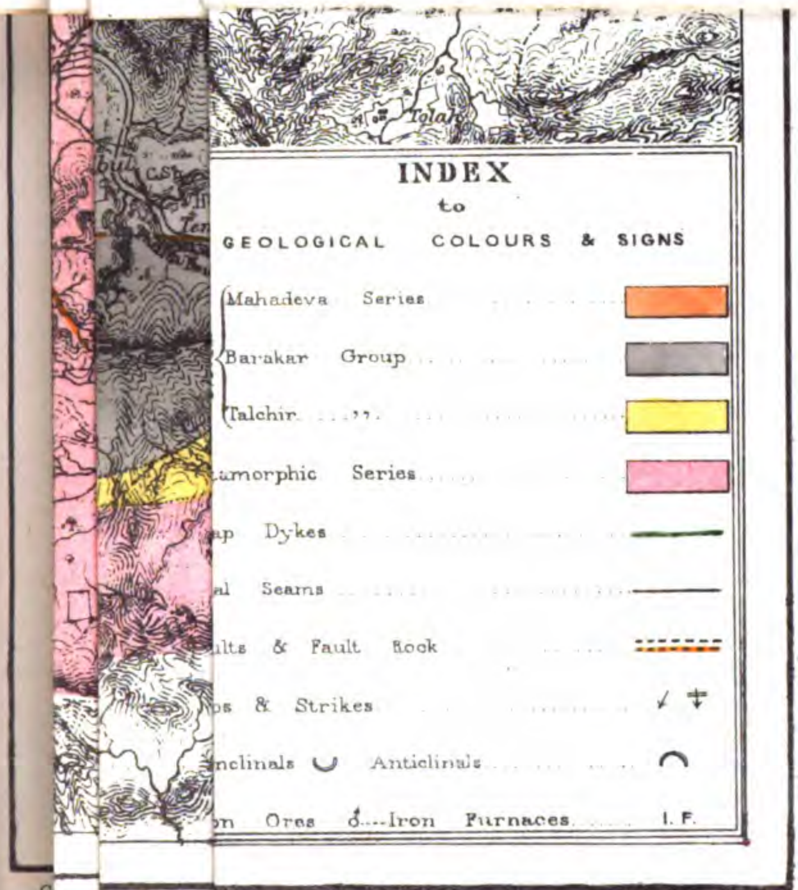
Much simplification of the questions at issue will ensue by omitting all such localities from consideration.

I shall conclude this section by giving a brief sketch of the present condition of the native iron works in the area.

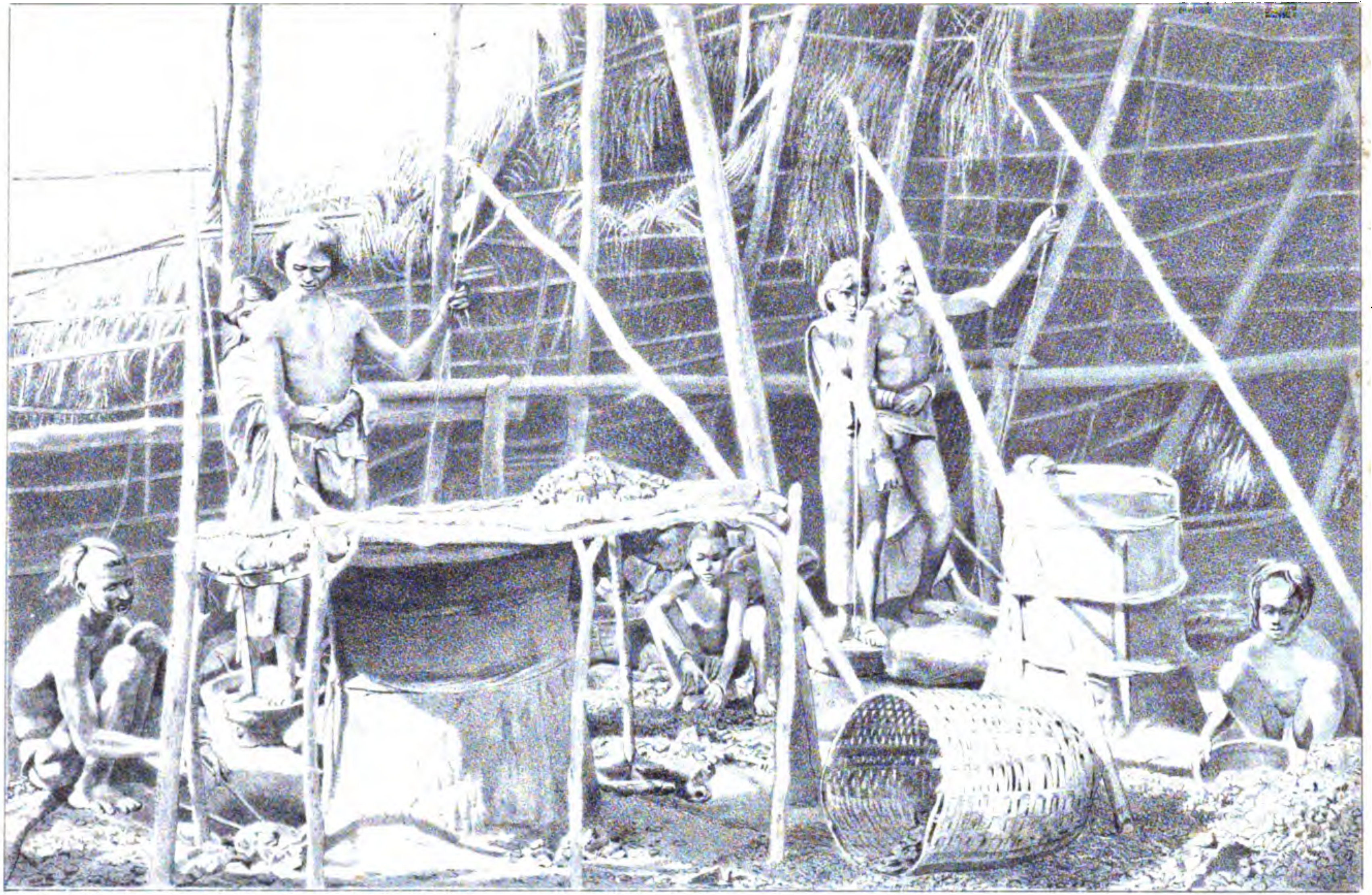
NATIVE IRON WORKS.

A photograph, for which I am indebted to the kindness of Mr. T. F. Peppe, has rendered it possible to give here a more life-like representation of the process of smelting, as practised by the Aguriahs, than has hitherto been published. In the lithographic reproduction of this photograph, M. Jules Schaumburg's artistic hand, which has done so much for the illustration of these volumes, will be recognized.

Although the direct process by which malleable iron is produced in native furnaces has often been described, and now finds a place in works on metallurgy, I venture to think that a few remarks on the subject, the result of my own observations, will not be inappropriate here. I have already, on a previous page, discussed the ethnology of the various tribes connected with the manufacture and working of iron.



of Captⁿ J. Waterhouse, Surveyor General's Office Calcutta. July 1878.



J. Schaumburg, Lith.

AGARIAH IRON SMELTERS PALAMOW.

The furnaces of the Aguriahs are generally erected under some old tamarind or other shady tree on the outskirts of a village, or under sheds in a hamlet where only Aguriahs dwell, and which is situated in convenient proximity to the ore or to the jungle where the charcoal is prepared. The furnaces are built of mud, and are about three feet high, tapering from below upwards, from a diameter of rather more than two feet at base to eighteen inches at top, with an internal diameter of about six inches, the hearth being somewhat wider. Supposing the Aguriah and his family to have collected the charcoal and ore, the latter has to be prepared before being placed in the furnace.

Dimensions of furnaces.

Three varieties of ore are recognized, *viz.* :—

Bali = Magnetite.
Biji = Hæmatites from coal-measures.
Dherhur = Hæmatites from laterite.

Bali is first broken up into small fragments by pounding, and is then reduced to a fine powder between a pair of millstones. The hæmatites (*Biji* and *Dherhur*) it is not usual to subject to any other preliminary treatment besides pounding.

A bed of charcoal having been placed in the hearth, the furnace is filled with charcoal and then fired. The blast is produced by the usual pair of kettledrum-like bellows, which are worked by the feet as in the accompanying illustration, the heels of the operator acting as stoppers to the valves. The blast is conveyed to the furnace by a pair of bamboo twyeres, and has to be kept up steadily without intermission for from 6 to 8 hours. From time to time ore and fuel are sprinkled on the top of the fire, the proportions used not being measured, but probably the operators are guided by experience as to the quantities of each which produce the best results. From time to time the slag is tapped off by a hole pierced a few inches from the top of the hearth. Ten minutes before the conclusion of the process, the bellows are worked with extra vigour and the supply of ore and fuel from above is stopped. The clay luting of

Blowing in.

the hearth is then broken down, and the ball, or *giri*, consisting of semi-molten iron, slag and charcoal, is taken out and immediately hammered, by which a considerable proportion of the included slag which is still in a state of fusion is squeezed out.

Blowing out.

In some cases the Aguriahs continue the further process, until after various reheatings in open furnaces and hammering, they produce clean iron fit for market; or even at times they work it up themselves into suitable utensils. Not unfrequently, however, the Aguriahs' work ceases with the production of the *giri*, which passes into the hands of the Lohars. Four annas is a common price paid for an ordinary sized *giri*,[a] and as but two of these can be made in a very hard day's work of 15 hours' duration, and a considerable time has also to be spent on the preparation of ore and charcoal, the profits are small. The fact is, that although the actual price which the iron fetches in the market is high, the profits made by the mahajans, and the immense disproportion between the time and labour expended and the outturn, both combine to leave the unfortunate Aguriah in a miserable state of poverty.

Refining.

Price of crude iron.

The price varies with the quality of the finished iron. But the average prices at which the merchants of Seraidih and Cheinpur respectively purchase are 5 and 6 pasiri (36 cutcha seers), say 50 lbs., per rupee.

Prices of refined iron.

In the Karanpura field I was told that the price was Rs. 9 a tangi = 4 cutcha maunds, that would be about Rs. 3 per pucka maund, a much higher figure.[b]

[a] At Nowatand, in the Karanpura field, the prices of *giris* by weight were—

		Rs.	
3	cutcha maunds for	1	in advance.
2 to 2¼	" " "	1	on delivery.

[b] Owing to conflicting, and often deliberately untruthful statements, and the varying values of weights and measures, it is difficult to obtain perfectly reliable statistics on these points.

At Dehree I believe the merchant receives Rs. 9 for a pucka maund. This is a very high price indeed = Rs. 252 per ton.

It remains only to give a list of the localities where iron is now manufactured—at present in Palamow and Toree, so far as I have been able to ascertain.[a]

Palamow—

Village.	Tuppeh.	Number of furnaces.
Hosir	Bari	1
Gowa	"	1
Kopeh	"	3
Hurilong	Durjag	2
Morwaie	"	3
Hetlee	"	10
Hutar	Doothoo	2
Aror	"	6
Korom Toleh	"	10
Titaro or Toleh.	"	3 ?
Binda	"	1
Chorhut	"	?
Neturhat	Simah	2 seen; others reported.
Chiparo	"	?
Khugori	Buskhol	?
Toree—		
Olerpat		1
Chitag		2
Balunuggur		2
Rajbar[b]		1
Bejrah		4
Kurmahi		?
Ghootam		?
Nuwada		?

[a] A list supplied to me from Daltonganj proved so inaccurate that I only give the names of places where I have actually seen furnaces.

[b] This is the only furnace excavated in a bank of clay which I have seen in this area.

Table shewing character of Iron Ores collected and examined in situ *in Palamow.*

Locality.	Formation.	Percentage of Iron.	Name of Ore.	Mode of occurrence.	Remarks.
Assayed—					
Aurunga. 1. Rajbar	Barakar	49·2	Red and brown hæmatites	Bedded; concretionary structure.	
Aurunga. 2. Palee river, section north of village.	"	45·3	Brown hæmatite	Ditto ditto	These all occur in the outlying area between Balunuggur and Chiru; the proper position. no doubt, for iron works.
Aurunga. 3. Kurmahee	"	56·6	Red hæmatite	?	
Aurunga. 4. Dudhuria	"	33·7	Black band, with free carbon	Bedded	
Aurunga. 5. Ghotam	"	39·4	Red hæmatite	Ditto	
Hutar. 6. Hills east of Sindhowrah	"	59·3	Brown "	Concretionary in sandstone	These, though good ores, do not occur with sufficient regularity or abundance to be of value.
Hutar. 7. Hetlee	"	43·5	Red and brown hæmatites	Ditto ditto	
Hutar. 8. Hurilong	"	45·3	Brown hæmatite.	Ditto ditto	
Hutar. 9. Neturhat	Laterite	45·5	" "	Bedded	An excellent and abundant ore, but occurs too far away from the coal-fields to be of much value.
Not Assayed—					
Aurunga. 10. Kolherwan, south of village	Barakar	...	Sandy concretions of red and brown hæmatites.	Bedded	These occur in the vicinity of Nos. 1 to 5, but are of inferior value.
Aurunga. 11. Hills south-east of Bijrah	"	...			
Aurunga. 12. Hooshloo	"	...			
Hutar 13. Korom Toleh	"	...	Brown hæmatite	?	Used by the Aguriahs.
14. Kurahi, north of Chongo	Crystalline or metamorphic.	Not less than 60 per cent.	Nearly pure magnetite	Irregular lodes and bands in hornblendic rocks.	Smelted by Lohars of Chorhut.
15. South-west of Kopeh	" "		Ditto	In granite veins	This is of no commercial value, but is smelted by the Aguriahs.
16. South-east of Kopeh	" "				
17. South-west of Monodag	" "		Ditto	Irregular lodes and bands in hornblendic rocks.	Abundance unascertained.
18. Rajhera, East of Mylee River	" "				
19. Lankha, near Kopeh	" "		Ditto	Ditto ditto	Fragments of ore strewn over a wide area.
20. Herhun	" "		Ditto	Ditto ditto	This is the most promising deposit of magnetite.
21. Morwaie	" "		Magnetite, partly altered into red hæmatite.	Occurs with fault rock	Abundance unascertained.
22. Hosir	" "		Ditto ditto	Found as loose gravel	Probably valueless.
23. Sat Barwah	" "		Ditto ditto		
24. Kotam	" "		Ditto ditto		

SECTION 3.—LIMESTONES.

Little remains to be added to what has been said of the limestones when describing the crystalline rocks. So far as quantity and quality go, the limestones on the west of the Aurunga field are eminently suitable for use as a flux for the iron ores. I fully expect that they will be found traceable from the position I have indicated north-eastwards in the direction of the village of Echak. This would bring them into nearer proximity with the iron ores of the outlier (*vide* map).

The other calcareous deposits alluded to in the course of the preceding pages will probably not prove to be of economic value. But the crystalline limestone near Sattarwah may contain better portions than that from which the sample was taken.

SECTION 4.—LEAD AND COPPER.

The only lead ore I have seen from this part of the country consisted of weathered fragments of galena, which were picked up on the surface not far from Bankhap three miles north of Balumath. When passing that way I did not know of the occurrence, and had no subsequent opportunity of visiting the locality. I received the samples from the Sub-Inspector of Police at Balumath. At Hesatu, about 14 miles to the north-east of Bankhap and within the limits of the Hazaribagh district, galena was many years ago reported to occur. I visited the locality, but found that a series of excavations had been made which had destroyed all trace of the outcrop, so that there was no opportunity of forming any opinion as to its character.

Some traces of copper were found by Mr. Forbes in a well sunk in the station of Daltonganj. A notice of the fact will be found in Mr. Forbes' Settlement Report. A few traces of the copper carbonates were to be seen in the heaps of stone near the well at the time of my visit.

APPENDIX.

THE TATAPANI COAL-FIELD.

Although but little is known regarding the field upon which the above name has been conferred, there is no doubt that it covers a wide extent of country, and is not improbably in direct connection with the tracts of coal-measure and younger formations which are known to exist on the borders of Mirzapore and Rewah, and in Chung-Bookhar, Koria and other parts of Sirguja. Should this surmise prove to be correct, there would be an area within the limits of the northern districts of Sirguja alone of, probably, 2,000 square miles of Gondwana rocks.

The first and only published allusion to this field that I know of is to be found in the account of Captain Franklin's remarks on the Palamow coal-field.[a] "On the 5th of May," (1830) we are told, "Captain Franklin reported his discovery of coal at a place called Chergurh in the district of Sirguja."

"This coal was of superior quality, being much more bituminous than the Singrah coal, but being situated in a mountainous and jungly country, and the navigability of the Kunhur river being doubtful, the prospect of the discovery proving useful was slender." This discovery was alluded to by Dr. McClelland in the Coal Committee's report.[b]

From the mention of the Kunhur as affording a possible means of transport for this coal, I am inclined to believe that Captain Franklin's Manpur should be identified with a place of that name which is marked on the Atlas sheet, 14 miles west of Tatapani; but it may perhaps be a wholly different locality, since it is spoken of in the Coal Committee's report as being 8 or 10 miles west of the Ramgurh hill in Lukanpur which is about the position of the Gej river, a tributary of the Husdoo, where there is reason to believe coal-measures do occur.

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[a] Gleanings in Science, vol. ii, p. 218.

[b] Calcutta, 1838, p. 69.

The position of Chergurh would settle the point, but so far I have been unable to find that place on the maps.

In the year 1866 Mr. Medlicott visited the eastern end of this field near the hot springs, and noted the presence of both Barakars and upper Panchets (Mahadevas), as is indicated on his manuscript route map.

After I had completed the examination of the area occupied by the Aurunga and Hutar coal-fields but little time remained for carrying on examination on the western side of the Kunhur; however, I was enabled to pay a flying visit to Tatapani. On a previous page I have given an account of my observations on the hot springs.

Besides the Barakars and Mahadevas I found a narrow margin of Talchirs on the east of the field, I saw no coal seams of value in the neighbourhood of Tatapani, nor did the people I interrogated seem to know of the existence of any.

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Taken from sheets 89 and 104 of the Atlas of India.

MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA.

GEOLOGY OF THE RAMKOLA AND TATAPANI COAL-FIELDS:

BY

C. L. GRIESBACH, F.G.S.,

GEOLOGICAL SURVEY OF INDIA.

PART 1.

GENERAL GEOLOGY OF THE AREA.

PHYSICAL FEATURES.

THE area examined during the season 1878-79 is situated between latitudes 23° 30′ and 23° 55′, longitudes 82° 50′ and 84°, comprising the north-eastern parganas of the Sirguja state, with some portions of South Rewa, and may roughly be defined as being the area between the rivers Kunhur and Rer. Within these limits the coal-field is bounded on the south by the great gneissic plateau of Chota Nágpur, the latter rising to about 3,000 to 4,000 feet, with steep escarpments facing the north. Originally the deposits belonging to the Gondwána series may have extended up to that long line of escarpment; but, the coal-bearing rocks having gradually subsided, the surface of the present lower levels has undergone extensive denudation by the Kunhur and Rer river systems, and now only patches of Talchirs and sandstones of doubtful age, filling up here

and there hollows in the metamorphic rocks, indicate the former extent of those deposits.

From a distance scarcely to be distinguished from the flat-topped gneiss plateaux, are the Mahadeva sandstone hills, so conspicuous towards the central west of the coal-field, forming, as they do, vast table mountains occupying the centre and composing the main portion of the Gondwána area in the vicinity of the Rer river.

I have only examined the basin between the rivers Kunhur and Rer, where I found the actual coal-measures exposed in patches lying within the areas of denudation of four tributaries of these rivers, and, for convenience of description, I divide the coal-field therefore into two groups, namely—

I. The eastern basin, belonging to the Kunhur river system, comprising—

A. The Tatapáni and Sendur river sections.
B. The Banki river sections.

II. The western basins, belonging to the Rer river system, comprising—

A. The Iria river sections.
B. " Morne " "
C. " Mahán " "

With the exception of a few miles of natural boundaries along the eastern and south-western limits of the coal-field, the latter is brought alongside of the metamorphic rocks by extensive lines of fault, here and there of remarkably straight direction, along which, as is to be expected, hot springs occur. The most remarkable ones are situated in the vicinity of the Tatapáni village near the Kunhur river; Mr. V. Ball has mentioned the occurrence of these springs and gives the temperature of some of them.[1]

[1] Mem. Geol. Surv., Vol. XV, Pt. I, p. 22.

Between Tharni and Lurghuta (one mile south of Tatapáni) I could trace evidences of a great fault, which is very well shown near the junction with the sedimentary rocks, where a ridge of fault-rock runs in the line of dislocation.

Fault.

The hot spring of Ganduáni is also situated in this line.

Hot spring.

Crystalline area.

Most of the time available had to be devoted to the coal-bearing rocks: it was therefore only possible to examine the crystalline rocks of the neighbourhood cursorily; but at least three great groups could be distinguished, namely, the oldest gneiss formation, crystalline schists, and granitic rocks.

Division of crystalline series.

The old gneiss formation.

This is met with in two areas: *first,* forming the great Chota Nágpur Páts and their slopes to the north, and *second,* the area north of the coal-field in the vicinity of the Rer river. The latter is probably connected under ground with the gneiss of the Páts, merely denuded to a lower level (about 1,400 feet) and in parts covered by younger rocks.

Gneiss.

The usual variety of rocks composing the Páts is a coarse, porphyritic gneiss, with bands of hornblendic rocks, here and there passing into a hornblendic gneiss traversed by numerous veins of pink pegmatite and of epidote.

Lithological character.

The profile of the Páts is characteristic enough, rising more or less abruptly into plateaux, and distinguished from the escarpments of the Vindhyans or the upper Gondwánas by more gradual slopes and irregular outlines, all covered by dense jungles.

I may here mention the occurrence of rock-laterite with trap on all the Páts as already described in former Memoirs.

Occurrence of laterite with trap.

The gneissic area north of the coal-field on the right bank of the

Rer river is somewhat different in general aspect. Though I believe it to belong to the same formation as that which forms the Páts of the south, this gneiss never rises to any great height, being confined to an almost uniform level of about 1,400 feet and less, only here and there rising in isolated rocks a few feet above the denuded surface of the country—the whole, as indeed the whole of the area examined, being covered by tree jungle. In this stretch of gneissic rocks we find the picturesque falls of Rokas Kas of the Rer river. The fall is not less than about 80 to 100 feet, and the water rushes through a series of narrow chasms to join in a rock-surrounded pool below, the whole forming by far the most striking picture in this part of the country.

Gneiss of the Rer river.

Rokas Kas Falls.

Crystalline schists.

These form two belts, one south, one north of the coal-field, and are certainly distinct from the main gneissic area.

Descending from the great Chota Nágpur plateau in the direction of Tatapáni, say *viá* the Chanderpur road, we traverse at first an undulating denuded area still belonging to, and connected with, the gneiss of the Páts. But before reaching the Gondwána basin of Tatapáni, we come across one or more anticlinal rolls, composed of metamorphic schists, apparently faulted against the gneiss and certainly faulted against the Gondwána rocks between Tatapáni and Khijuria-t.

Anticlinal folds in schists.

I have shown the sequence of these rock groups in fig. 1 of Plate I. Standing on the slopes skirting the Gobra hill (3,220 feet) south of the deserted village of Gugra, we observe gneiss of a porphyritic character *in situ*, traversed by numerous veins of pegmatite. This gneiss forms all the lower hills around the base of the Chunderpur Páts, of which the plateau on the right (south) of the profile is a continuation (about 3,500 feet) situated near the village of Chunderpur. It is there capped by sheets of trap in common with a large part of the southern gneiss plateaux, here and there associated with rock-laterite.

Towards the left (north) of the profile the anticlinal folds of schist, as above described, form a series of low rolling hills. In the distance the continuation of the Páts towards Chatania is visible. The schist hills slope gradually down towards the Tatapáni basin, where (5 in fig. 1, Plate I) the Talchír boulder bed and shales are seen, at once distinguished from the former by the dry jungles of thorns so characteristic in all the older Gondwána rocks.

Sandstone-like gneiss.

There is a variety of hornblendic gneiss remarkably like decomposed sandstone in appearance, with quartzose schist dipping at a high angle towards the gneiss on the south, but forming a great fold as the dip turns round to the north again. The strike is east-north-east to west-south-west, the same as the great bounding fault which cuts off this area and throws the Gondwánas against the schists.

Second area of metamorphic schists.

Another area, but strategraphically related to the preceding, forms a fork inclosing the gneiss of the Lurgi-Chandaura hills (Mandru 3,373 feet, Andru 3,232 feet), and stretching in a south-west direction, forms the low hilly country near Pertábpur.

Ridge of the watershed of Rer and Kunhur.

The extreme eastern extension of the fork is composed of the sandstone-like gneiss, thin-bedded and in parts resembling mica schist; it rests on the old gneiss formation on which Dhanuar is situated. It is *in situ* in the nullah flowing north of the village in an east-west direction, and dips at a high angle from the gneiss. From thence in a south-west direction stretches far away a low range of hills of nearly uniform height, and forming at the same time the watershed between the confluents of the Rer and Kunhur rivers. This range is entirely composed of mica schist with associated

Quartz schist.

quartz schist and quartz rock. Following it from east to west, I found it near Kobi, in the Goga stream section, composed of pure quartz rock, which changes near Rámpur into a quartz rock with a few leaves of white mica disseminated through it. Crossing the range from Rámpur to Kapaut, we find also patches of

hornblendic schists and garnet rock associated with this micaceous quartz schist. The bedding is somewhat obscure, owing to the dense vegetation covering the whole country. Though there is much of the rock exposed in patches and isolated masses, yet the bedding can only be observed here and there.

Garnet rock.

The general character of a micaceous quartz schist remains the same, with the only difference that the lamination is more distinct towards the west; and near Maiapur the rock is almost a mica schist. The southern prong of the great fork above mentioned is different in aspect and lithological character. It forms a lower undulating country, stretching away to the gneiss Páts south of it, and well exposed in all streams between Dumarkola and Pertábpur. Though still quartzose, the rock has here more the character of a mica schist, extremely brittle and friable, being made up of very fine sandy grains of quartz and minute laminæ of white mica, with garnets as accessory mineral. Separated from this area by the granitic ridges is a series of true mica schists, hornblende schists and quartzites dipping from the main mass of the granitic ridges; their strike is nearly east-west, and the dip is high, about 55°, to north.

Changes into a mica schist.

Pertábpur mica schist.

Third area of metamorphic schists.

Isolated masses of similar schists are met with and were mapped within the granitic area, probably left standing when the intrusive granite forced its way in between the beds of metamorphic schists, thus probably explaining also the disturbed and folded character of the bedding of the schists.

Isolated masses of schist in granite masses.

Another and by far the largest area of these schists was traversed north and east of the Gondwána basin. Beginning east of the basin immediately below the Talchirs near Mitgain we meet mica schist, strike nearly east-west, dip north; a little further north, forming No. 326 H. T. (1757),[1] we meet with

Fourth area.

Mica schist.

[1] On the 1-inch map.

chlorite schist, strike west-north-west, east-south-east, dip north. Near the northern boundary of the coal-field, about a mile west of Gumharia, the strike of the crystalline schist becomes north-west to south-east, dipping north-east, at 80°. It is there true mica schist, which rises up to considerable heights in the Khori hills. The road from Chumra to Kakankoja on the Kunhur traverses this ground, which is formed by one or more steep folds in the schist, there seen to alternate with a quartz rock of pebbly character. With the exception of a few isolated masses of intrusive granite, the rocks between the Khori hills and the gneissic region above described consist chiefly of mica schists and quartz schist, forming a slightly undulating country of an elevation of about 1,200 to 1,300 feet, with deeply eroded river-courses. Some of the folds rise somewhat higher and form these isolated masses, cut into deep valleys and sharp ridges by the numberless streams. The strike near Bluthar Chura, as indeed nearly all over this area, is north-west to south-east, dip north-east, but varying occasionally to an east-west strike. Numerous quartz reefs traverse the area, mostly in an east-west direction.

Chloritic schist.

Many hornblende dykes occur; they may be taken as altered trap dykes. Such is observed east of Chura, in the Kursa stream; direction north-west to south-east, thickness about 20 yards. It is a very close-grained rock, and has caused some local disturbance near the junction with the mica schist, which there shows the same strike as the dyke, with dip to the south-west.

Hornblende dykes.
Trap dykes.

Near the boundary with the gneiss area of the Rer the folds in the mica schist gradually turn round to a north-east to south-west direction—in fact, following the boundary line of the gneiss, which, I believe, is a natural one.

Boundary with gneiss natural.

Granitic rocks.

These rocks occupy a considerable portion of the area examined, and probably form the base on which the Gondwána rocks of the more central parts of the coal-field rest. As exhibited on the map, we now find two long strips of

Granitic rocks.

granitic rocks north and south of the field, of from three to four miles width on either side. Besides these, I came across several detached masses of intrusive granite north of my area, as well as numerous pegmatite veins in the older rocks, especially the old gneiss plateau of Chota Nágpur.

Extent.

As near as possible, the boundary-line of the granite with the metamorphic rocks is parallel with the line of faults which have lowered the Gondwána basin. An examination of the southern mass of granite between the villages of Khijuria-t (east) and the limits of my map on the Mahán river (west) shows that it probably includes both intrusive and metamorphic granite; but the hills are quite inaccessible, being covered by dense jungle and not traversed by any roads or even jungle paths, so that a distinction could not be made on the map. The section between the Mahadeva sandstone on the north side and the Gobra hill on the south exposes a coarse-grained granite, showing all the constituents of the granite in single hand-specimens even, with isolated masses of garnet rock amongst it, the relation of which to the granite could not be ascertained. Near the Chalgali section the minerals composing the granite get separated, and we meet there large masses of nearly pure felspar with scarcely any quartz or mica in it. The best exposure in the granitic ridge is seen along a rocky path leading from Lotki to Bhagwánpur. Starting from the former place (Lotki), we soon leave the mica schist (quartz schist) and enter the granitic ridge. There, veins of granite traverse the schist for long distances, and prove beyond doubt the intrusive character of the rock. Towards the centre of the granitic ridge (about 3,000 feet high) we meet with a finer variety of granite, consisting of equal proportions of quartz, felspar, and white mica; but between that point and Lotki a coarse-grained porphyritic variety is seen, containing the same constituents, with tourmaline as accessory mineral, sometimes in large crystals.

Garnet rock.

Intrusive character.

Lithology.

It is possible to find large blocks, consisting of nothing but milky

quartz with tourmaline. In others, these two minerals are predominant, the mica and felspar being scarcely distinguishable. Similar varieties are found on the northern slope of this mass, passing gradually into a coarse-grained variety of granite, but without the tourmaline.

Tourmaline granite.

Along this section I observed several isolated strips of mica schist, much crushed and contorted, and showing signs of having been subjected to further alteration, by heat or otherwise; near the junction with the granitic mass, particles of felspar are found disseminated in the mica schist, and give it a gneissic character. The strike of the mica schist masses is generally that of the boundaries with the metamorphic schists, which also corresponds with the general strike of the latter in this region. Probably these masses are connected with the main mass of mica schist, and the intrusive granite has simply forced its way between the beds of the schists, separating some portions of them.

Mica schist inclosed.

The parallel section between Maiapur and Pahár Karua is very similar, excepting that I did not meet with any remains of crystalline schists in the granitic area.

The boundary between the schist and the granite I found about a mile north of Maiapur in crossing a small stream south of Deuri. For about two miles the path traverses a well-defined plateau of a finer-grained variety of granite, which here and there shows a somewhat gneissic character, but which I cannot separate from the main granite area.

Gneissoid granite.

North of the coal-field, between Palgi and Churka, granitic masses appear again, apparently a continuation of the granites of the south. In general outline of hills, as well as in lithological character of the rock, the granite of this ridge is identical with the rocks of the southern area. Tourmaline granites prevail, and form the main mass of the eastern extension of the ridge, sending out long spurs into the neighbouring schists.

Area north of the coal-field.

Lithology.

sula is complete, even as to the colour. Again we meet with a mass of rocks, but this time of calcareous character, inclosed in a great fold of metamorphics between Munshári and Bageswar on the southern slope of the Himalayas. Here are shales, more massive beds, and conglomerate beds, the debris in which is all, however, made up of limestone. Supposing the identity of these formations with the lower Vindhyan jasper conglomerate and with the beds near Kandia, it would assign a pre-Silurian age to the latter, probably Cambrian.

Slates of Jajáwal.

South of Jajáwal, in the Rámkola pargana, I met with a narrow strip of hard dark blue slates, resting on mica schists, and dipping at a high angle (about 55°) to the north-east. They are overlaid there by gritty Barakar sandstone. Most probably, these slates belong to the same group of semi-metamorphic beds, of which the Kandia beds are the type in the Rámkola field. Possibly the semi-metamorphic rocks described by Mr. Ball[1] from the Bisrámpur field also may be included in this group, but I have not seen his section. It is not at all unlikely that formerly this group has extended over a much larger area south of Sirguja, and from there the red quartzite boulders of Vindhyan type may have been derived, so common in the Talchirs of my area.[2]

The Gondwana Series.

The coal-fields under description occupy a principal eastern arm of the main central area of Gondwána rocks, stretching from Tatapáni due westward for more than 200 miles to near Jabalpur, and from the latter position extending for 300 miles by a long prolongation to the south-east to near Sambalpur, into close proximity of the Talchir field in Orissa.

Extending over larger area formerly.

There is no doubt that the Gondwánas spread originally over a much wider extent of country than they do at present, and numerous detached remains of Talchirs and uncertain sandstones plastering over some of the metamorphic rocks

[1] Records, 1873, pt. 2. [2] *Vide* Plate. II, fig. 2.

north and south of the actual basin indicate their probable former extent. Starting from Tatapáni, we find a natural contact of Gondwánas resting on metamorphic schist along the eastern and north-eastern boundaries of the field. From near Gumharia a nearly east to west fault, indicated by fault-rock and much crumpling of the strata, extends along the whole northern boundary, defining an angle in it near the boundary of the Rewah State, where we find a high escarpment of Mahadeva sandstone abutting against the metamorphics. From there the boundary is again natural, and we find Talchirs resting on the gneiss.

Boundaries mostly faulted.

From Tatapáni eastwards we see the coal-field cut off on the south by a great fault, throwing the several beds of Gondwánas successively against crystalline rocks. Here and there the fault has traversed the latter and left natural boundaries with the Gondwánas, exposing the Talchirs as lowest beds, which probably covered the floor of the basin over the entire surface. Such a natural boundary we find along the exposure of Talchirs west of Kandia, between Bhagwánpur and Dandkarua, and along the exposure in the Mahán-Rer nullahs; the section through all the rocks of the Gondwánas near Námadháka (about five miles south-by-west of Dandkarua) I fancy is brought about by denudation only, as there can be little doubt that the line of contact with the granite is faulted.

Few natural boundaries.

Roughly speaking, the Gondwána area examined forms a narrow bay (from twelve to about thirty miles wide) of sedimentary rocks in the metamorphics, preserved from denudation only by their having subsided between lines of nearly parallel faults. The remaining portions of Gondwánas left at higher levels, resting on metamorphics, have been removed by denudation, though isolated patches of them are still found, here and there, outside the area of the field, thus clearly indicating the former extent of the basin.

Present extent of Gondwánas.

Much denuded.

Barakars.

A considerable thickness of beds, consisting of sandstones, flaggy beds and shales, with numerous seams of coal, is found resting on Talchirs everywhere within the limits of this area and cropping out beneath beds belonging to upper groups of the lower Gondwánas. Next to the Mahadeva sandstones and shales, they occupy by far the greatest extent of ground, and are readily distinguishable from the underlying Talchirs, the boundary with which is very sharp and well marked. An unconformity with the Talchirs is at least very probable in some sections. The boundary upwards is not well defined, as the change, both lithologically and palæontologically considered, is gradual. With the exception of the most eastern development of these beds near Tatapáni, the whole area of Barakars is traversed by long faults, especially near and parallel to the great boundary fault of the north-eastern part of the coal-field. The upper series (Mahadevas), occupying the centre and main extent of the Gondwána basin, stretches eastward as a long strip, being there faulted against the metamorphic rocks on the south side. In this field, at least, the Barakars are very distinct from the Talchirs, and lithologically the change is *sudden* to the fine-grained flags and sandstones with shales, all of which contain Barakar fossils. Where the junctiou is natural, the Barakars dip inwards and apparently conformably under the Mahadevas along with the intermediate Raniganj and Panchet beds.

Lithological character of Barakars.

Boundaries.

The rocks most frequently met with are :—

1. Sandstones, fine-grained, greyish-yellow, with varieties of white and reddish gritty sandstones, often false-bedded, and alternating with flaggy micaceous beds.
2. Micaceous, thin-bedded, grey, shaly or flaggy sandstones, containing carbonaceous matter.
3. Coal-seams of variable thickness. As yet three distinct bands were met with ; they occur mostly in the middle of the group,

and one near the top and just below the iron measures of the Raniganj group.

The largest and best seams are in the vicinity of the Morne river, where we find a series of coal seams, ranging from a few inches to 1 foot, and a fine seam of a little more than 7 feet, which remains pretty constant; towards the west this seam thins out considerably, and in the Suknai nullah the same bed decreases rapidly to 3 feet 6 inches. In the nullah east of Budatand, falling into the Morne river, there is a band of coal with shaly partings of 17 feet, probably representing the 7 feet seam of the Morne river sections.

In the Barakars of the northern part of my area, the character of the rocks composing the group does not change, and we still meet with micaceous shaly sandstones and shales, containing coal, but of inferior quality, and having thinned out considerably; but as the Barakar beds are only brought up by faulting, it is possible that the coal-seams are only some of the top ones, also seen in other sections, and that the better seams, which are elsewhere constant, are hidden beneath.

Towards the extreme western tracts of the coal-field near the Banki nullah (tributary of the Morne river), the Barakars are faulted against the Mahadeva sandstone, and consist of hard, gritty sandstones, with numerous pot-holes.

Thickness.

The entire thickness of the Barakars, as calculated from the Tatapáni sections, is probably not more than 900 feet.

Raniganj.

Roughly defining it, the Barakar group is characterised, as already stated, by fine-grained sandstones, dark micaceous and carboniferous shales, and coal-seams with decidedly a Barakar flora.

Lithological character of Raniganj.

Though it is difficult, in some sections even almost impossible, to lay one's hand on the exact point of junction of Barakars and the next overlying group, yet it is not difficult to define in general the character of this latter, which is most

distinctly developed in this field. Placed side by side, the specimens with fossils from this group could not be distinguished from those of the Raniganj field, but other petrological characters are somewhat different, conspicuously so by the absence of coal. The Raniganj here consists chiefly of white felspathic and gritty sandstones, white shales with numerous Raniganj fossils (plants), with thick beds of clay iron ores, ferruginous sandstones, with nodules of iron ores and iron shales, these latter well shown in the Sendur river sections. In short, whereas the Barakars are distinguished by the presence of coal-seams and carbonaceous shales, we find the Raniganj remarkably rich in iron ore bands, or nodules in other beds, and thin bands of iron shales.

Thickness.

The approximate thickness of the whole group is probably not more than 1,300 feet. Deposits of this horizon are probably represented in all sections, but I have only mapped them as such where fossil evidence supports this view.

Panchets.

Lithological character of Panchets.

Under this head I have included all the sandstones, grits, clays, and shales which occupy the space between the Raniganj and the typical Mahadevas, from which it is not always easy to distinguish them. The commonest rock of this series, and which occupies a large area, both vertically and horizontally, is a red clay, changing here and there into red clay shales and clayey sandstone. These rocks are generally alternating with white and yellowish hard shales, and in many sections changing into an olive-green clay, sometimes mottled both colours. It is invariably overlaid by white friable sandstones, or similar red sandstones, which latter are difficult to distinguish from similar beds in the Mahadeva sandstones,—especially as some beds of the former have even the brown gritty appearance of the latter with ferruginous partings.

Grit or conglomerate.

At several localities I have found in the Panchet horizon a coarse brown or red conglomerate or grit, made up chiefly by round or angular pieces of quartz, the latter sometimes attaining the size of

pigeon eggs. These beds then form low hills of rounded outline, but easily distinguished in appearance from Mahadevas. I have included this rock in the Panchets, though I have no fossil evidence to support my view, whereas in the Panchets proper I have found several characteristic forms of plants.

Thickness.

The thickness of the Panchets in the Tatapáni sections is estimated at from 1,200 to 1,500 feet, but it thins out considerably towards the west.

Mahadevas.

Escarpments.

Rocks, chiefly sandstones, belonging to this series occupy by far the largest extent of ground. Unlike the rest of the Gondwána rocks, which do not rise above 1,500 feet above sea level in my area, the Mahadevas form bold escarpments, many of them perpendicular, even overhanging sometimes, and plateaux of from 2,000 to 3,000 feet above the sea.

Whereas the Barakars are remarkable for the dryness of soil, which is very sandy, and consequently the rivers of which rarely contain much water during the dry season, the Mahadevas by decomposing, as they do, into a heavy clay soil, give rise to perennial streams. Owing to this circumstance is also the freshness of the sâl and mixed jungles on ground composed of Mahadevas, whereas Barakars and Talchirs invariably only can boast of dry thorns and species of Mimosa trees.

Lithological character of Mahadevas.

I could not divide the Mahadevas farther in this area. Nearly the whole mass is composed of thick beds of reddish-brown, ferruginous, gritty sandstone, generally false-bedded and remarkable for hard ferruginous partings, which cut up the beds in a most singular manner, and, after the rock has undergone disintegration by denudation, remain standing like thin walls and long ridges in the mass of sandstone.

Ferruginous partings.

Sometimes these partings make a network in the sandstone, and after the latter has been worn away, they form a cellular mass of striking appearance. Here

and there, thick layers of red iron ore are intercalated between the Mahadevas; and a few earthy beds are met with, the only beds which have yielded fossils.

Thickness of the Mahadevas.

The total thickness probably does not exceed 800 feet, this being the difference of height between the top of the Tamor escarpment and the level below, which is composed of older rocks.

Jointing.

The rock masses of the Mahadevas are traversed in all directions by joints; the steep outlines of the escarpments no doubt owe their existence to this extensive jointing. As masses of the rock are undermined by the rivers below, blocks, more or less approaching a cubical shape, separate from the cliff above and come down the hill sides, thus always preserving a freshly broken surface to the escarpment, as shown in fig. 1, where, owing to the

Fig. 1. Mahadeva escarpment of the Tamor hill, valley of the Mahan river.

inclination of the strata, the face of the cliff is actually overhanging, the rocks splitting off along the joints, which are mostly normal to the line of bedding.

The boldest and highest escarpments of the Mahadevas face the south, rising to nearly 3,000 feet (Tamor hill, 2,758 feet), as shown in the above sketch, fig. 1; the sandstones there form quite inaccessible cliffs, high above the older Gondwána rocks below (see fig. 3, pl. V), whereas towards the north they gradually flatten down to the general low level of the older rocks, with a few remarkable exceptions, as in the Pipra hill, 2,004 feet in elevation and which is nearly 800 feet above the level of the surrounding country (see fig. 1, pl. V).

Proceeding from east to west, I noticed the Mahadeva sandstone first in the long north to south escarpment of Sendur-Pipraul; it is formed of thick massive beds of gritty ferruginous sandstone dipping 20° to the west. From there the Mahadeva ridge ascends in one or two great steps of bold outlines, covered by dense jungles, the supposed haunts of numerous dacoits. The lithological uniformity is remarkable; for miles and miles the character of the rock remains the same, a coarse gritty reddish-brown sandstone.

Slope towards the north.

Towards Rájketa the hills gradually subside into lower levels; until seen from the north near that village, they appear but as small hillocks above the low undulating ground.

In fig. 2, pl. VI, I have shown the natural profile of this part of the Mahadevas as seen from the south, from near Bara Barthi, in the Upper Morne valley; the dip is there rolling about 20° towards the north-west, and in consequence the outline of the hills is rounded and totally unlike the usual contour of hills composed of this formation.

Ferruginous partings.

But the rock is there, as elsewhere, composed of a succession of coarse brownish-red sandstones and rough grits with occasional pebble beds. Ferruginous partings are found in every bed—not always along the line of bedding, but traversing it and forming sometimes a network, the meshes of which vary in size from a few inches in diameter to many feet.

Many thick layers of good hæmatite occur amongst the sandstone beds, but the native iron-smelters never make use of this or similar ores, but invariably only of very inferior ones of the upper Barakar beds.

Rámkola plateau.

The most considerable patch of Mahadevas of my area is the large plateau of nearly square outline, in a denuded bay of which is situated the village of Rámkola. It presents a steep precipitous escarpment (fig. 1, p. 20) towards the south, with a more or less level surface, covered by jungle, traversed and denuded by numerous perennial streams. It is nearly surrounded by copious outbursts of trap, which appears on the surface both as huge dykes of many miles length, and on the south-eastern and eastern face of the escarpment as great intrusive sheets, spreading for miles over the lower rocks. In fig. 1, pl. VI, I have given the profile of the eastern escarpment of the Rámkola plateau, in which the Mahadevas (1) are seen to slope to the north-west, with the trap (2) forming the intrusive sheet beneath the strata of the sandstone.

Trap.

The beds of the Mahadeva plateau, fig. 1, Plate VI, slope gently towards the north-west, excepting near the bounding fault, which extends from near Turpa (Rer river) towards the east, accompanied and flanked by parallel trap dykes (see fig. 3, pl. VI), where the dip increases considerably, and in one or two minor instances approaches the vertical. But this north-western corner of my Mahadeva area (see fig. 2, pl. V) is noteworthy for the fact that there I found a few traces of fossils. In a dark reddish-brown earthy shale between beds of Mahadeva grits, north of Khond, I found a few traces of plants, which Dr. Feistmantel determines as :

Fossils.

Alethopteris, spec.
Glossopteris ? [1]

As shown in the last-mentioned section, the Mahadevas are thrown directly against the metamorphics, south of Turpa, the strata being raised up to about 45° to 50° south. A few miles to the south, however, the bedding becomes quite normal—almost horizontal—and is penetrated by several trap dykes running more or less in an east-west direction. South

[1] For the naming of my specimens, as well as for the forthcoming description of a few new species of fossil plants from this coal-field, I am indebted to Dr. O. Feistmantel.

of Burwar, I found in the Dhursot nullah the trap shown in fig. 2 (p. 25), beyond which the dip increases to the south or south-west, the sandstone beds containing a few earthy beds of shales with the above fossils.

Probable overlap.

Though I have observed throughout the coal-field an apparent conformity of the Mahadevas with the older Gondwána rocks, it is yet probable that the former overlap the lower beds here and there. The nature of the jungle-covered country, however, makes it extremely difficult to decide this point. Near the south-eastern boundary of the field on the low ridge of metamorphics separating the Tatapáni field from the Bisrámpur field, patches of coarse reddish-brown grits and sandstones abound; they form only a thin covering on the metamorphics, and are evidently only the remains of a vast extent of Mahadeva rocks which once probably covered a great area, connecting the various fields.

TRAP.

Altered trap.

I have certainly come across three varieties of trap rock in my survey. A semi-metamorphic trap forms a dyke of somewhat less than a mile in length, and only some 20 yards wide in the mica schist south-east of Chura. Near the dyke a disturbance is visible in the mica schist, the latter dipping from it. The direction of the dyke is north-west to south-east. It is an extremely dense variety, and almost resembles hornblendic rock.

Basalt caps on gneiss.

A basaltic rock caps nearly all the main gneiss plateau south of the coal-field, and forms continuous sheets of perhaps not more than 50 feet thick. Remains of the trap sheets are found on the top of all the plateaus wherever the original surface has been preserved; on the lower hills, which evidently have undergone extensive denudation, we miss these traps. On the tops of the Lamti-pát and Gulgul-pát, fig. 1, pl. I, we find laterite associated with the trap, but the exact connection was not observed, owing to the dense vegetation covering the whole.

But the main mass of the trap rocks in my survey is situated within the boundaries of the coal-field, where it occurs in the form of dykes and intrusive sheets. Having reached the western extension of the basin before I finished the centre, I came on large sheets of trap in Barakars, and there took it at first for contemporaneous trap, owing to the regularity of the apparently interbedded sheets between strata; but I soon found out my mistake when I saw the continuation of the same traps traverse the Gondwánas as enormous dykes and without any regard to the stratification or age of the beds, cutting through all rocks from metamorphics to Mahadevas.

Dykes and intrusive sheets of basaltic trap.

The principal spreads of intrusive sheets are noticeable between the villages of Majurdaki and Gorgi, where they have pushed between beds probably of Barakar age and the overlying Mahadevas; subsequent denudation has then exposed great sheets of this trap, the latter showing nearly throughout a spheroidal structure.

A similar but even larger sheet is found in the valley of denudation of the Morne and tributaries, extending across the whole width of the valley, covering the Barakars and loosing itself below the Mahadevas. Here and there the former are exposed in patches where the trap was removed by denudation, and good examples of the contact effects are then shown. Towards the north this intrusive sheet is connected with a dyke little less than half a mile in width, which extends in a north-westerly direction beyond the Morne river and cuts through the Mahadeva sandstone.

The narrow strip of trap north of Námadháka (5 miles north-west of Maiapur), at the foot of the Kalhota hill, is probably part of the intrusive sheet which is hidden by the Mahadeva sandstone of the Churipat hills.

The northern half of the basin examined is traversed by numerous trap dykes, most of them being situated along faults. Some of the traps in the Nowadih sections (north of Damni) and of the Bhalui nullah section might be explained as being intrusive and repeated by faulting; but there is clear evidence

Dykes along faults.

that the traps, many of them very narrow, along the great east-20°-north to west-20°-south fault along the Iria nullah are dykes erupted along the fault; also the east-west dykes which run nearly parallel from near the Banki nullah westwards are clearly along lines of fault. This is especially well seen near the contact of Mahadevas and Barakars of the Pipra hill, which is faulted, the lower beds of the former disappearing towards the east against the Barakars, and apparently dipping below them. The long dyke south of that locality, which at first runs nearly east and west, turns sharp round to the south-west near Maihewa, near which village the trap has intruded between beds of Barakars laterally and still connected with the dyke.

A similar example of intrusive trap was found in the Dhursot nullah (Rer river), where a north-west to south-east dyke, about 8 feet thick, has penetrated right and left into joints of the Mahadevas, forming veins of only a few inches thickness and conforming exactly to the surfaces of the joints, filling up every crevice in the sandstone, as shown in the accompanying fig. 2:—

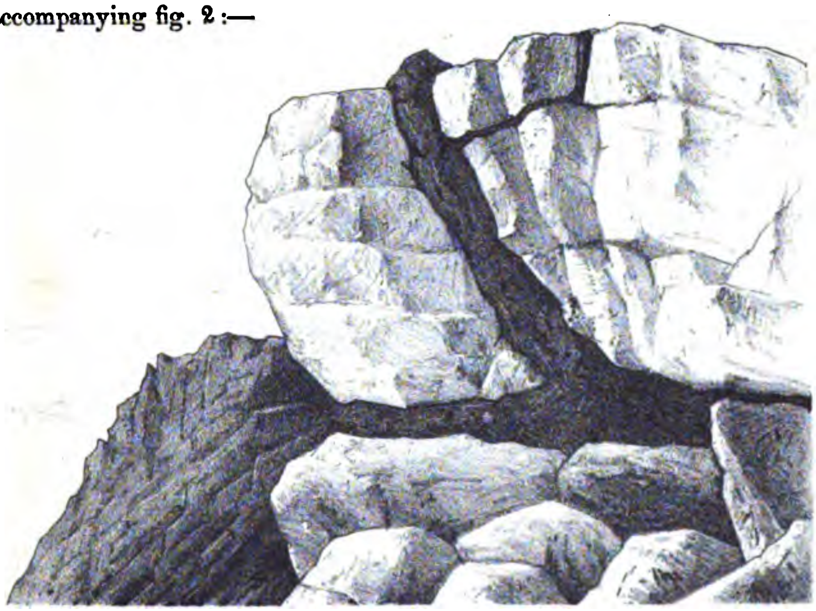

Fig. 2. Trap dyke, filling up joints in Mahadeva sandstone north of Khord, in the Dhursot nullah.

The dykes south of the Pipra hill continue for some distance into the metamorphic rocks west of the Gondwánas, and two of them are found south of Chiraikund amongst granitic rocks.

Numbers of parallel dykes are found near the north-western boundary of the Mahadevas in the neighbourhood of Naogai and Assandiah, some of them penetrating into the adjoining metamorphics. In fig. 2, pl. I, I have shown one of these long ridge-like dykes of trap south of Assandiah. They are only covered with very little soil, and the onion-like structure of the trap is visible all over, and thus the presence of the trap can always be detected with the greatest ease. A long dyke (see fig. 3, pl. VI) of this trap extends along the valley of the Rer, forming a high and precipitous wall of nearly north-west to south-east direction. It is connected in the south with the great intrusive sheets of the Jajáwal area shown in fig. 3, pl. V.

RECENT DEPOSITS.

Before closing my description of rock-groups, I must briefly allude to the enormous deposits of recent sands and clays covering, more or less, the entire surface of the area examined by me. They present the greatest uniformity throughout the area, and are in no way different from the great alluvial deposits observed in the Palamow districts. It is mostly a fine silty deposit of sands with a few partings of clay, and here and there layers of pebbles from the neighbouring rocks. The greatest deposits were found in the northern half of my area, in the neighbourhood of the Ledho and Iria nullahs, where banks of 80 to 100 feet of them are exposed by the rivers. They usually show beautiful examples of false bedding, and here and there alternating layers of sand and pebbles. Wherever exposed, they have weathered into high, almost perpendicular, cliffs, and are washed out into a semblance of organ pipes. Not less common are examples of pillar structure, caused by the denudation of all the sand and clay, except the portion protected by capping pebbles or stones. The recent deposits covering the Talchirs are remarkable in so far that they contain a great deal of kunkur limestone of precisely the same character as that described from Daltonganj.

PART II.

DESCRIPTION OF SECTIONS IN THE COAL-FIELD.

I.—THE EASTERN BASIN (TATAPANI, GIDHI) BELONGING TO THE KUNHUR RIVER SYSTEM.

A.—TATAPANI AND SENDUR RIVER SECTIONS.

The boundaries of the lowest Gondwána rocks with the metamorphic rocks being natural between Tatapáni and Mitgain, I obtained complete sections through all groups represented in this field.

Talchirs in Tatapáni Nullah.

Descending the Tatapáni nullah (tributary of the Sendur river), I found Talchirs immediately below the hot spring; they form beds of fine conglomerates, much denuded and merely plastering over the metamorphic rock beneath, which crops up in isolated patches. This is soon followed by the typical boulder-bed with intercalated beds of fine-grained yellowish green sandstone. Boulders of irregular shape and evidently worn, derived from the surrounding metamorphic rocks, are cemented together by rounded pebbles of the same material, as well as fine-grained sandstone and clays. Also here and there huge blocks of metamorphic rocks are found in this mass. The general direction of the strike is north-east to south-west, and rolling to north-west, under an angle of from 30° to 40°. Near the bend of the nullah at Moua-t the strike is north-south, the dip west. In fact, the strike is so changeable and the dip rolling, as usual in the Talchirs of this basin, that it is difficult to record all observations on the map. This conglomerate is overlaid by about 15 feet of an irregular bedded whitish-green sandstone with a few boulders and gravel of metamorphic rock scattered here and there. Above this sandstone again follows boulder-bed. The villages of Tithert and Bhormi are on Talchirs, the boundary of which with the metamorphic rock below is well seen about 500 yards east of the latter village.

The triangular-shaped hill range north of Tatapáni is composed of metamorphic schist, chiefly mica schist, and the boundary of the Talchirs skirts this hill along the western escarpment, the Talchirs dipping away from it.

1.—Section along the nullah north of Bithiau.

In all the nullahs north of Bithiau (deserted village) we observe the following section in descending order, fig. 1, Plate III—ground between the Sendur river and the Metamorphics :

D.—IRON SHALES ...	17.	Clay shales alternating with thin leafy iron shales.
C.—BARAKARS ...	16.	*Coal-seam* 5.′
	15.	Shales alternating with thin-bedded sandstone.
	14.	*Coal-seam* 1.′
	13.	Shales, carbonaceous.
	12.	*Coal-seam* 6.″
	11.	Sandstone with bituminous shales alternating.
	10.	*Coal-seam* 2′.
	9.	Bituminous shales.
	8.	*Coal-seam* 10″ passing into—
	7.	Thin bed of sandstone.
	6.	Clay shales, dark, with traces of fossil leaves.
	5.	*Coal-seam of 1′ thickness.*
	4.	Shales, carbonaceous.
	3.	Thin *coal-seam* passing into—
	2.	Shales, micaceous and grey.
	1.	Sandstone, fine-grained ochre-coloured.
B.—TALCHIRS ...	9.	Boulder-bed.
	8.	Sandstone, bright olive-coloured, irregular bed and thinning out.
	7.	Shales of same character as bed 1.
	6.	Sandstone.
	5.	Pebble conglomerate.
	4.	Thick-bedded sandstones.
	3.	Talchir boulder-bed of typical character.
	2.	Sandstone, whitish-yellow, with bands of pebbles.
	1.	*Shales*, reddish-brown and olive-coloured, traversed by jointing in three or more directions, thereby separating into small cubes and long needle-shaped forms. Here and there gritty, with scattered boulders of metamorphic rocks.
A.—METAMORPHIC SCHISTS.		

Thickness of Talchirs.

It is very difficult to arrive at a true estimate of the thickness of the Talchir beds, owing to the rolling character of the dip; but it is probable that the estimate of about 700 feet for the Tatapáni sections comes very near the truth.

Thickness of Barakars.

The strike and dip of the Barakars remain perfectly uniform in the Bithiau nullah; the former is north-south, and dip is at 20°, to west, and the total horizontal length of the Barakar section being 2,640 feet, the thickness is exactly 900 feet. This is confirmed by the sections north of Tatapáni, in the Chechra section and neighbouring nullahs, where I found a total horizontal length of section of 4,336 feet with a dip of 12°, to west-20°-south, which results in a total thickness of Barakars of 902 feet.

Iron shales.

The iron shales (17 to 18) which are intercalated between the Barakars and the following groups are very characteristic, and occur near the junction of the Bithiau nullah with the stream which rises near Moua-t.

Raniganj base-bed.

Though there is no break of conformity between this series of Barakars and the following beds, yet there is a sudden and decided change of lithological character. On the iron shales rest masses of clay iron ore of considerable thickness, which being *in situ* in the river, have been denuded into the most grotesque forms. Evidently lying on it conformably, are masses of thick-bedded sandstone (19) of ashy-grey colour with angular grits of quartz and large leaves of mica. Carbonaceous markings and indistinct plant-remains are found throughout the rock. It is very friable and crumbles away. Inclosed in this mass of gritty sandstone are lenticular masses of light grey micaceous shales, without fossils. Above it follows a pebble conglomerate of similar general character. These sandstones I consider as the base-bed of the Raniganj series, and it remains pretty constant in all the Tatápani sections.

2.—Section along the nullah south of Agar-t.

Section along nullah south of Agar-t.

As the Moua-t nullah, and subsequently the Sendur river, run along the strike, more or less, of the Raniganj series, the section is not very clear; but we obtain a very good one along the nullah south of Agar-t, where in descending order the following series occurs (see fig. 1, Plate III) between the Mahadevas and the Sendur river:

G.—MAHADEVAS . .	Sandstone of the Pipraul escarpment, described above, page 21.
F.—PANCHETS . .	47. Shales. 46. Conglomerate with angular fragments of metamorphic rocks. 45. White friable sandstone. 44. Clays, clunchy. 43. Thick beds of fine-grained white friable sandstone and shales alternating with grits. 42. Thin bed of yellow, hard, ferruginous clay shales. 41. Bed of carbonaceous clay. 40. Thick-bedded white gritty sandstone, alternating with grey shales. 39. Fine-grained white sandstone, very sandy. 38. Sandstone with bands of iron ore. 37. Clay shales. 36. Grits, very friable, chiefly consisting of pebbles and fragments of quartz. Dip 15 to 20° S. W. 35. Grey shales. 34. Coarse conglomeratic sandstone and grits. 33. Clunchy shales. 32. Coarse-grained sandstone. 31. Clunchy clay shales. 30. Felspathic sandstone and grits. 29. Thin bed of grey clay shales with boulders of beds beneath.
E.—RANIGANJ . .	28. Quartz sandstone alternating with red shales. 27. Yellowish finer-grained sandstone with beds of red sandstone. 26. Thick-bedded red ferruginous sandstone with pebbles of quartz separating into jointed masses. 25. Thick masses of quartz sandstone with occasional beds of finer-grained yellow sandstone.

E.—RANIGANJ—contd.

24. Friable coarse-grained felspathic sandstone with bands of iron ore.
23. Sandstone and shales.
22. Band of iron ore, 1 foot 6 inches.
21. Calcareous, friable quartz sandstone, 1 foot 7 inches.
20. Conchoidal grey clay shales, 9 inches.
19. Grey sandstone, micaceous, with carbonaceous markings, occasional nodules of clay iron ore. The thickness is not seen, but about 8' is exposed.

D.—IRON SHALES

18. Ferruginous sandstone and bands of red iron ore.
17. Iron shales with clay iron ore band.

Raniganj.

The entire thickness of the Raniganj series in this field is 1,550 feet, thus considerably exceeding the Barakars. Further west I observed that the Raniganj, of precisely similar lithological character and containing typical fossils, thins out considerably and the Barakars are developed in greater force. The general dip is the same as that of the Barakars, namely, about 20° west or south-west, strike nearly from north to south. The physical conditions under which the Raniganj were deposited must have been very different from those prevailing during Barakar times, at least in this field. Instead of dark bituminous clay shales and fine brownish-yellow sandstones with coal-seams, we meet here generally felspathic sandstones, ferruginous shales and bands of iron ore, resting on the characteristic micaceous ashy-grey sandstone bed No. 19. No trace of a coal-seam is visible, and, though I have found no fossils in this section, it is not difficult to identify this series with typical Raniganj elsewhere well developed in the coal-field.

Panchets.

The following series of Panchets begins with a contact bed made up of boulders and debris from the beds beneath No. 29, and from this point the dip gradually decreases to about 15° south-west, the strike turning more to the north-west to south-east; the total thickness of the group in this section is about 1,300 feet. The beds composing it can readily be distinguished from those forming the Raniganj. They are, as seen in the accompanying section, chiefly clays, variegated or red, alternating with shales and

gritty sandstones. No fossils were obtained in this section, but in the same beds further westward several typical Panchet fossils were obtained.

Mahadevas.

The Mahadeva sandstone of usual type follows, but it is not clearly seen how this group is related to the underlying Panchets in this section; but it is certain that the general strike and dip is the same, and it may be assumed to be conformable.

This succession of beds, dipping at about 20° to west, remains tolerably constant along the eastern part of the field and of the Pipraul-Sendur escarpment, and there is no doubt the groups represent a natural boundary of the field; whilst south of the Sendur river, the whole series is cut off by the great Tatapâni fault, as is well seen in all the small nullahs, which join the Sendur river from the south.

The Mahadevas are somewhat disturbed near the fault, and some remains of them are found in hills and isolated blocks south of the fault, as, for instance, near Khijuria. The general dip of the Mahadeva sandstone is about 15° to 20°, to west-20°-south, forming a high and precipitous escarpment facing east.

North and north-west of the described sections, the dip of the beds of Gondwánas gradually decreases, and as the strike turns round to the west the bedding becomes almost horizontal.

3. *Section in the Nullahs between Chechra and No. 326 H. T., north of Mitgain.*

In descending order we find (fig. 2, Plate III.) upper part of section obscured by recent deposits :

C.—*Raniganj.* 24. Thick-bedded, coarse, gritty sandstone, felspathic, with nodules of ferruginous sandstone inclosed. Eroded in potholes.

23. Purple thin-bedded sandstone, thickness 3′ 6″.

22. Dark-blue shales, with clay iron ore nodules 2′.

21. Felspathic sandstones 5′.

20. *a.*—Dark-blue and grey shales, clunchy, with fossils, thickness about 2′ 6″.

b.—Purple and blue shales with fossil leaves, thickness about 3′ 6″, lying nearly horizontal except near outcrop, where the dip is 5° west.

19. Grey micaceous sandstone 14′.

B.—*Barakars.*

16, 17, & 18. Coal and coaly shale 5′; blue shales 2′.

15. Purplish and greenish-blue shales 5′.

14. Coal-seam 6″, rather shaly.

No exposure, about 40′.

Fault.

C.—*Raniganj.* 19. Carbonaceous grey sandstone 150′, same as bed 19 of the Agar-t section.

B.—*Barakars.* 16. Coal, with shaly partings, 3½′.

15. Shales 5′.

11 &c. Sandstone 21′.

7? Ferruginous brown sandstone 115′.

C.—*Raniganj.* 19? Micaceous shaly flags, purplish, with carbonaceous sandstone.

B.—*Barakars,* are much faulted, and, as the nullah is extremely sandy, it is scarcely possible to make out the sequence. At first the beds are much obscured by sand for about 500 yards, followed by beds which I identified with beds of the Sendur sections as follows:—

4. Purplish-red and grey shales, about 14′.

2 & 3. Grey carbonaceous sandstone, locally faulted and crushed.

1. Red and grey shales, 14′, with the following fossils:—

Vertebraria indica, Royle.

Glossopteris communis, Fstm.

„ *browniana* (*indica?*).

„ *damudica,* Fstm.

A.—*Talchirs,* are represented in this section in great thickness, and are typical in lithological character. Great masses of the boulder bed, with associated marly shales showing the jointing as usua, of greenish-grey colour, occasionally reddish-brown and mottled. The strike is north-west to south-east, with a dip to the south-west of from 25 to 30°. With it occur large masses of fine mealy yellowish sandstones, with layers and bands of boulders, rapidly swelling or thinning out, being then often replaced by boulder beds. The sandstones are worn into

grotesque forms by denudation in the river and are full of pebbles. In fig. 1, Plate II, I have represented this worn sandstone, which is seen well in the Mitgain nullah. The dip is rolling and the strike changeable. Near Mitgain the strike is north-east to south-west, and the dip south-east. In the nullah north-west of Mitgain they rest on mica schist, and near the No. 326 H. T. on chloritic schist.

B.—Banki river Sections.

4.—Section along the nullah east of Gidhi and in the Banki River to Panri village.

In descending order: fig. 3, Plate III.

The numbers correspond with those of beds in the Sendur river section.

G.—*Mahadeva sandstone.*

F.—*Panchets.*

Dip 8° south-west {

- 38. Soft greenish-yellow sandstone.
- 37. Grey shales, with conchoidal fracture and much jointing.
- 36. Ditto, but with covering of oxide of iron on joint surfaces.
- 35. Purple shales, with carbonaceous markings and fossil traces.
- 34. Purple clays, with fossils.
- 33. Micaceous and ferruginous sandstone.
- 32. Light-coloured grey shales with carbonaceous markings.
- 31. Ferruginous micaceous sandstone separating into square blocks.
- 30. Soft yellowish sandstone.
- 29. Ferruginous hard sandstone with beds of pebbly softer sandstone jointed.

E.—*Raniganj.*

Dip rolling ... {

- No exposure.
- Rolled boulders of nodular clay iron ore in sand.
- 23. Yellowish thinly laminated shales, nearly horizontal.
- 22. Grey shales with fossils, passing into beds above containing—
  - *Glossopteris angustifolia*, Bgt.
  - " *retifera*, Fstm.
  - " *communis*, Fstm.
- 21. Felspathic white sandstone.
- 20. { Dark shales and sandstones, much disturbed.
  Shales with conchoidal fracture, with flaggy sandstone beds, horizontal and rolling, much jointed.
- 19. Thick beds of sandstone, with strings of quartz pebbles, jointed.
- No exposure.

B.—*Barakars.*

10. *Coal-seam* exposed 2'.
9. Shaly sandstone 1' 2".
8. *Coal-seam* 1' 2".
7. Sandstone 8' 2".

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Fault.

16. Coal-seam 8' 6".

Fault.

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19. Thick-bedded sandstone.
18. Thin band of clay iron ore 6".
17. Grey shales, nearly horizontal.
16. Coal-seam, partly hidden under water.
15. Fine-grained grey sandstone, micaceous; strike east-west, dip slightly south, locally disturbed, about 5' thickness.
14. Shales.
13. Sandstone, strike east-west, dip 8° south, but rolling.
12. Shales.
11. Ferruginous sandstone.
8, 9, 10. Coal-seam and shales 1', south-east to north-west, dip 10° south-west.
6, 7. Ferruginous sandstone and shales.
5. Coal-bed 1'.
1 to 4. Ferruginous sandstone, showing a very corroded surface; much hidden by alluvium.

A.—*Talchirs.*

Of typical character; boulder bed with silty sandstones and shales of conchoidal fracture, dip 50° south-west.

Resting on metamorphic schists.

Descending from the village Pánri, which stands on mica schist, to the Banki nullah by the road to Pipraul, we find Talchir boulder bed and shales resting on the metamorphics in the river, raised to 50° probably by lateral pressure, this boundary being near the great subsiding fault, which farther to the west cuts off the coal-field on the north.

The section through the Barakars is completely analogous to the sections already described in the Bithiau nullah. The greatest subsidence in the Tatapáni portion of the field having taken place towards the

south-west, some disturbances and faulting are visible in the second half of the Barakar section, which are not difficult to recognize. But the Raniganj and Panchet groups are much obscured by the covering of alluvial deposits in all the gullies leading down from the Mahadeva hills.

5.—*Section along the nallahs left and right of Banki River west of Chumra.*

This section presents considerable difficulties in comparing it with former ones, being much faulted, and certain beds have a peculiar local development, others evidently have died out. But descending from the Mahadeva sandstone which there has been denuded considerably, sloping gradually down to the level of the Banki valley, we find in descending order, fig. 1, Plate IV :—

I.—PANCHETS . .	21. For some distance no exposure; after that, here and there a friable felspathic sandstone grit and conglomerate beds, probably of Panchet age. 20. Ferruginous mottled sandstone, almost ironstone. 19. About 20 feet of sandstone. 17. Red friable conchoidal shales, breaking up into small fragments through extensive jointing, with intercalated bed of yellow shales (about 20 feet). Top bed a white clay.
II.—RANIGANJ . .	16. About 50 feet thickness of shales, some very ferruginous, alternating with clay shales and bands of ferruginous nodules of spherical structure, containing the following fossils: *Glossopteris angustifolia*, Bgt. " *indica*, Bgt. " *communis*, Fstm. These shales are jointed in several directions, and consequently break up into small needle-shaped forms; they are much faulted and several times repeated. Dip 10° south-west. 15. Sandstone 8′. 14. Shales 6′.
III.—BARAKARS . .	13. Shaly coal, the base hidden below water; dips under low angle south-west. (16 of Bithiau section, p. 28).

Fault.

ASCENDING.	
II.—RANIGANJ . .	16. Light-coloured shales with thin partings of sandstone containing— *Glossopteris angustifolia*, Bgt. „ *indica*, Bgt. (Schmp.) „ *communis*, Fstm. 17. Ferruginous sandstone.
The last two beds are repeated several times by faulting.	16. Thick bed of clay shales of conchoidal fracture, drab and yellowish coloured, with oxide of iron on joint surfaces.

Fault.

III.—BARAKARS . .	3. Sandstone. 4. Purple and bluish shales with micaceous layers on partings and fossils:— *Glossopteris communis*, Fstm. 5. Sandstone with bed of mica shale full of carbonaceous matter. 6. Dark shales with shining coaly matter about 4′, containing a bad *coal-seam of* about 1′ thickness. 7. Ripple-marked brown sandstone, 3′. 8. Sandy shales and hard flaggy sandstone. 9. Hard flaggy quartz sandstone, 1′. 10. Dark carbonaceous shales (jointed) 2′. 11. Flaggy quartz sandstone, 1′ 6″. 12. Clays and grey micaceous shales. 13. Barakar sandstone and shales with coal 6′ 4″, position not clear.

The detailed section of bed 13 (16 in Agar-t section) is as follows:—

In descending order:

Sandstone	2′	
Carbonaceous shales . . .	0	3″
Shales	0	7″
Sandstone	1′	
Shaly coal	1′	
Shales	1	
Shaly coal		6″
	6′	4″

This section is not always clear, owing to the numerous local disturbances and repetitions by faulting. In fact, the field is so greatly

shattered, especially towards the western and south-western portion of it, that a strict correlation of the beds is not always possible. But it is very probable that beds 16, 17, 18, and 19 correspond with beds of precisely similar lithological character seen in the Sendur river section near Mitgain and in the nullah near Bithiau (north of that place).[1]

The coal is nowhere seen to advantage, and the quality seems very inferior; it is, in fact, only a lignite, and does not promise to be profitable for working.

6.—Section along the Nullah north of Meguli.

In descending order from south to north :—

South: Banki Nullah

5. Thin-bedded sandstone with shales and a thin bed of COAL; dip gradually flattening.
4. Light-coloured shales with bands of reddish shales and some ferruginous hard bands, with concentric nodules of iron ore.
3. Soft clay shales, dark coloured near base, lighter towards top. Strike as sandstone. Containing *Glossopteris ovalis*, Fstml. n. sp.
2. Hard quartzose white sandstone, alternating with softer beds and shales, probably repeated by faulting, strike nearly east to west, dip 20° south. A few nodules of ironstone are scattered throughout the mass.
1. Micaschist, strike north-north-west to south-south-east, dip 80° north-east to east.

North:

BANKI NULLAH.

Both this section and the exposure in the nullahs south of Gumharia show that the Talchirs are overlapped by the Barakars, and that the latter rest directly on mica schist, being represented by hard quartz sandstone with ripple marking on surface of beds. On the map I have marked this group of shales and sandstones as Barakars, but Dr. Feistmantel considers the form of *Glossopteris* contained in bed 3 as a Raniganj form: it may be that beds of that horizon, which is well represented in the sections west of this locality, strike across. It is at any time

[1] See fig. 1, Plate III.

very difficult to make out the relations of beds in the dense jungles which cover every square mile of ground in this field.

7.—Section along the Nullahs between Bagra (North) and Lawa (South).

In ascending order :—

North : village of Bagra on mica schist. Just south of that place a series of low ridges extend in a nearly east-westerly direction, being composed of a hard porous (cellular) rock, resembling Rauchwacke. This rock puzzled me a good deal at first, but afterwards I found that it is merely filling up the long lines of fault, scarcely without interruption, and I obtained clear sections through it afterwards near Palgi and also south of Lundra, where the relation to the other rocks is unmistakeable. Immediately south of this ridge I found sandstone and shales of probable Raniganj age faulted against the old rocks, but so shattered that a succession of beds could only be obtained here and there.

In descending order, a short distance further down stream, I could make out :—

1. An unevenly bedded red grit or sandstone in thick masses, very soft, strike north-west to south-east, dip south-west.
2. Thin-bedded red hard ferruginous sandstone, in places with a good red iron ore, denuded into furrows and ridges on the surface, not unlike some of the partings in the Mahadeva sandstone. Quartz pebbles and grits in strings.
3. White sandy beds, very soft, dip 5°, to south-west.
4. Coarse-grained sandstone.
   Trap dyke, showing concentric structure here and there, strike east-west, thickness 36′.
5. Sandstone, ferruginous.

These beds, however, are so much shattered by local faulting that it would be impossible to say with any degree of certainty to which group they belong; and in addition, the nullah does not afford a good section there, the rocks being obscured by alluvium. But a little further down, clay shales of a Barakar appearance come in, which I have classed as such on the map. From there the section is an ascending one, but still, and for some distance, disturbed by faulting. However we get

again into the ferruginous grits and sandstones with clay iron ore, characteristic of Raniganj. Further on again—

Ascending :—

Panchets:

1. Red plastic clay of Panchet type.
2. Purple and yellow banded gritty sandstone, towards base, a band of hard shale 1", and partings of micaceous shales.
3. Purple banded clays, nearly horizontal, thickness 6', with parting of micaceous shale.
4. Sandstone, 9' thickness.
5. Ferruginous ditto.
6. Mahadeva sandstone.

8.—*Section in the Sita Chua Nullah.*

Nearly the same succession of rocks, crushed and tumbled together in the most perplexing manner, is met with in the dry nullah of Sita Chua, running into the Banki nullah east of Dhamni. North of the former village I met metamorphic rock (mica schist and quartz schist). In the nullah near the village I met a white mealy soft sandstone, not unlike what I saw in the former section (No. 301 H. T. is composed of it); here and there it is mottled with reddish beds, but otherwise it resembles the Mahadevas. It is hollowed out in large pot-holes, one of which is worshipped as Sita Chua (the rise of Sita). In the many windings of this rivulet, only here and there rocks appear *in situ*, the rest are hidden by sands and rubbish. In the bed of the Banki nullah near the junction with the Sita Chua nullah Raniganj clay shales are exposed, and a little further west in the bend of this river trap is *in situ*, and forms a dyke across it; I traced this dyke for miles in a nearly east-west direction towards Nowadih. The rocks, however, right and left of the Banki nullah, are so much denuded and the whole country levelled down to the river banks, that no exposure is seen for miles round until we get to Dhamni, where red clays are seen, overlaid further on by Mahadeva sandstone. These red clays occupy invariably the place just below the Mahadevas, and most probably represent Panchets. This section, and

the one previously described, would not be intelligible if I had not obtained a clear section between Nowadih and Gargori.

9.—Section in the Nullahs (tributaries of the Banki river) between Gargori and Nowadih.

In descending order: fig. 2, pl. 4.

SOUTH.

M. Mahadevas.

Ferruginous sandstone.

P. Panchets.

1. White sand or mealy sandstone.
2. Red and purplish sandstone and marls.

R. Raniganj.

1. Grey micaceous and thin-bedded sandstone.
2. Micaceous and carbonaceous shales with fossils:
   Glossopteris communis, Fstm.
   „ *angustifolia*, Bgt.
3. Marly ochre-coloured shales, with numerous traces of leaves and equisetaceous stalks.
4. Hard yellow sandstone.
5. Micaceous shales and sandstone.

Fault 1.

M. Mahadeva sandstone.

P. Panchets.

1. White marly sandstone.
2. Red clays and marls.

R. Raniganj.

1. Shales.

Fault 2.

P. Panchets.

1. White sands.
2. Purple clays.

R. Raniganj.

1. Shales and sandstone.

Fault 3.

P. Panchets.

Marls.

R. Raniganj.

Shales.

Fault 4.

T, trap dyke, showing all gradations from hard igneous rock to concentric structure and greenish tuff, in the latter condition resembling Talchir shales. The Panchet shales are altered into a burnt brick-like appearance, with steel-blue contact surfaces.

P. Panchets.

Marls and clays, dipping north, from the trap.

M. Mahadeva sandstone.

Fault 5.

R. Raniganj.

Shales, dipping 7° north.

T. Trap dyke.

P. Panchets.

Red clays and marls, with white, somewhat chalky, sandstone above.

M. Mahadeva sandstone.

Fault 6.

R. Raniganj.

Shales with—

Glossopteris, spec. nov.

T. Trap dykes.

P. Panchet.

Clays.

M. Mahadeva sandstone.

Fault 7.

T. Trap dyke.

Bounding fault with fault-rock.
Metamorphic quartzite.
North, village of Nowadih.

Undoubtedly the great lowering of the area by the fault near Nowadih has crushed and shattered the beds near it, mostly in long parallel lines, the traces of which could be observed in the former sections.

II.—THE WESTERN BASINS, BELONGING TO THE RER RIVER SYSTEM.

A.—Iria River Sections.

The country between Dhamni and Karamdiha forming the watershed between the Banki and Iria nullahs is very difficult of access; dense jungles cover most of the ground, and great deposits of alluvial sands and clays extend all over that part of the field, so that the nullahs seldom expose rock *in situ*, and that only at long intervals.[1]

10.—Regai Nullah and neighbouring country.

In the Regai nullah, near the village, I met with clayey sandstones with marly partings of a dense red brick colour, which I noticed in many sections intercalated between the Panchets and Mahadeva sandstone, and which I connect with the former. They are lithologically identical with the Panchets near Chumra and near Lawa already noticed, and I have also met them in great force in the southern outcrops of the basin near Kachia, overlying the Raniganj series; all are most probably to be correlated with the red and purple clays of Lawa. Between the Regai and Iria nullahs calcareous gritty sandstones, very soft, alternate with and pass into this red sandstone. Partings of ferruginous plates of slag-like appearance remind one of the Mahadeva sandstone, but still I separate the group from the overlying sandstone of that period.

These sandstones all show false bedding, sometimes as much as 45° with the plane of stratification; an overlap occurs in every section, so that it is very difficult to correlate beds of even adjoining sections. The red clays usually appear between the sandstone beds as thin partings and often as lenticular masses of considerable dimensions. Here and there the red clay passes into motley lavender-coloured clay shales in which I found fossils a short distance down the river.

A long fault of east-by-north direction separates the mass of Panchet sandstones and shales, and along this line of fracture a narrow

[1] Several names that have to be used in describing this wild country are only marked on the 1-inch maps. Special copies of those maps can be obtained at the Geological Survey Office by any one wishing for the detailed information.

dyke of trap may be traced for a considerable distance. Between Palgi and Thurkunda the sequence of beds is the same as in the Nowadih section, but between that locality and Karamdiha the relations are very obscure, only here and there reddish sandstone or clays indicate the presence of Panchet rocks.

11.—Sections in the Ledho Nullah north of Karamdiha.

Near the village of Karamdiha trap is *in situ* and forms the hill on which the village is situated. But immediately north of the place, in the Ledho nullah, I found :—

2.—*Raniganj beds* consisting of a series of shales and thin-bedded sandstones of a type which is best seen near Parasdiha in the Morne river, as will be shown further on. These beds are exposed north-east of the Karamdiha village on the slope down to the river; the strike is north-east to south-west, dipping about 5° to south-east, below the upper beds, which I shall notice presently. The cliff consists in descending order of:—

(*d*) light-coloured soft shales, and sandstone 1'; (*c*) clay shales, very friable; (*b*) carbonaceous shales with a thin bed of leafy *coal;* this bed resembles a similar layer of carbonized leaves seen in the Reonti cliff, to be described further on. Remains of *Glossopteris communis*, Fstm., and *G. angustifolia*, Bgt., were found in these shales. (*a*) Dark conchoidal shales.

1. Barakar shales and sandstones of the typical character; the base is not seen, being covered up by the alluvial deposits of the river.

A short distance higher up the river, at a place where two small streams join the Ledho, south-east of Sihai, a group of beds are seen consisting in descending order of—

3. *Panchets.* *k.* Gritty sandstones with ferruginous partings, overlaid and interstratified with red clays and gritty sandstone.

i. Red shales	Dip 5 to 7° north-east.
h. Ferruginous sandstone	
g. Whitish grey marly shales ...	

f. Red shales.

e. Thin beds of sandstone of Mahadeva character with ferruginous partings.

d. White shales and thin-bedded sandstone.

c. Red shales 3′6″ of the same type as those seen in the Lawa section (7).

b. Ferruginous yellow and variegated sandstones and shales with bands of iron ore, with an irregular band of gritty sandstone of about 8′ thickness, thinning out to about 1′6″ within a distance of 20 yards. The dip is rolling, about 5° to north-west.

In places where the upper beds are denuded, this sandstone is overlaid by a coarse breccia consisting chiefly of fragments of Mahadeva-like sandstone, ironstone nodules, with rolled fragments of metamorphic rocks cemented together by a matrix of ferruginous matter, the whole, however, only of recent origin.

a. Whitish-grey marly shales with—

Glossopteris angustifolia, Bgt.

„ *communis*, Fstm., and

Thinnfeldia-like ferns.

Ascending the southern branch of the Ledho nullah, south of Salsuli, I got again into the Raniganj group dipping below the above beds of Panchet type.

12.—Sections between Karamdiha and No. 506 H. T., including the Lower Ledho, Chorki, and Kundkepi Nullahs.

The river bed between Karamdiha and Bhalui is so sandy that only few exposures are met with, but it is probable that the isolated cliffs seen belong to the Panchet group, being a continuation of the Panchets of the upper Ledho nullah. The first rock *in situ* is found in the great bend of the river about a mile west of the village, where in *descending* order I found :—

Panchets. *f.* Yellow marly clays with ferruginous nodules.

e. Red marls.

d. Yellow marly clays.

c. Light grey marly shales, very friable.

b. Dark and variegated clay shales, towards top micaceous and shaly, with

Glossopteris communis, Fstm.

Pecopteris ? odontopteroides, M.

a. Light grey marly shales and clays, very friable.

The dip is rolling, but generally to the south; the whole is overlaid by thick-bedded masses of grits with strings of pebbles very similar to the Lundra grits which will be described further on.

Between the villages of Bhalui and Boder the beds are much shattered, and a series of local parallel faults run across in a south-west to north-east direction. Since we find trap dykes along these lines of disturbances, similar to the Nowadih section, it is probable that the local disturbances are only owing to the eruption of trap. The Ledho and Bhalui nullahs afford the only opportunities for examination, so it was impossible to trace the lines of faults beyond the beds of the rivers, and I had to trust to conjecture for the remainder.[1] In the Ledho south of Bhalui I observe the coarse Panchet grits to dip southwards, where they are suddenly cut off, thrown down to the level of the Barakars, which dip there at 8°, to east; descending I found:—

a. Thin-bedded sandstone and shales.

b. Grey clays with patches of variegated shales with—

Vertebraria indica, Royle.

Glossopteris communis, Fstm.

c. Ripple-marked sandstone with partings of iron ore.

d. Green micaceous marly shales, somewhat like Talchirs in appearance.

e. Marly yellow and reddish shales of great thickness, near base friable grey shales.

f. *Thin bed of coal.*

g. Same as *e*.

h. Coal with shaly partings 5′ 2.″

i. Greenish marly shales, breaking into small rhomboidal fragments, with intercalated grey shales and a parting of bituminous shales 1.″

j. Great thickness of bituminous shales.

k. Grey micaceous fine-grained sandstone.

l. Blue shales.

Trap dyke.

Barakar sandstone and shales.

Trap dyke.

Barakar sandstone jointed into brick-like masses.

Trap.

Blue shales with coal seams above sandstone beds, dipping about 70° east.

[1] This remark applies also to the Sita Chua and Nowadih sections; rocks appeared *in situ* only in the beds of the streams, and the lines of fault had to be continued in perfectly straight lines as shown on the map, owing to the obscurity of all the intervening country.

Fault.

Raniganj shales and sandstones in high cliffs along bank of Ledho nullah, dip south-east, gradually changing to south.

Exposure in Bhalui Nullah.

Descending: dip 6°-7° to east.

Barakars. *h.* Blue clay.

g. Same as *e*, with parting of thin bed of micaceous sandstone.

f. Thick bed of micaceous grey sandstone.

e. Friable dark blue and ferruginous shales.

d. Same as *b*.

c. Bituminous shales.

b. Thin ferruginous bed.

a. Greenish and blue shales with nodules of iron ore.

The Chorki Nullah.

Dip 25° east, exposes a section through the following Raniganj rocks; descending:

p. Thin-bedded sandstone and shales, reddish micaceous, very soft.

o. Micaceous clayey shales.

n. Hard micaceous sandstone.

m. Coaly shale with thin seams of *coal*.

l. Banded leafy sandstone.

k. Hard thick-bedded sandstone, fine-grained.

i. Thin-bed of calcareous soft sandstone.

h. „ „ micaceous shaly sandstone (Reonti type).

g. Thin beds of clay shales.

f. Same as *h*.

e. Ferruginous shales.

d. Soft thick-bedded sandstone.

c. Ripple-marked thin-bedded sandstone (as *h*).

b. Thin-bedded ferruginous and variegated sandstone and shales; marly and micaceous at places, with concretionary structure.

a. Thick beds of ferruginous sandstone.

About a mile south of Kundkepi these beds are cut off by the bounding fault, which throws them against the metamorphics—here tourmaline granite.

In all the small rivulets falling into the Iria nullah east of Colhuar village (not on the map), we find shales and sandstone evidently belonging to the same group of rocks (Raniganj) dipping below the hill No.

506 H. T., which is composed of red grits and sandstone with red clays below, which I identify with the Panchets, as shown in the eastern sections. These strata cover the Raniganj below, forming an oblong patch on them.

South of the Iria nullah the Raniganj series is cut off by a fault, probably the same which I observed south of Karamdiha, but here it is well shown in all the nullahs coming from Kotrahi and Garia. The direction of this fault is then west-10°-south to east-10°-north, the fracture is nearly perpendicular with a slight dip to the south, bringing the sandstone and shales on the same level with the adjoining Mahadeva sandstone. The fracture is filled up with fault-rock, very ferruginous and hard, which is less affected by subaerial denudation than the adjoining rocks, and consequently is left as a wall-like ridge of about 5 feet in thickness standing high above the sandstones.

13.—Section along the Balsotha Nullah.

The Balsotha nullah and the nullahs west of it falling into the Iria and Morne have denuded away the whole of the Panchet grits and Raniganj beds and left only the Barakars in shattered remains, bounded on the north by the fault between Chorki and Geruáni, and along the south and west by the Mahadeva hills, which are faulted against the Barakars, as is well seen in all the river sections.

The section along the Balsotha Nullah between Saura on the north and the Iria nullah south is as follows :—

Saura village is on tourmaline granite, and the fault boundary with the Gondwánas is shown well in the bed of the river, where a ridge of porous fault-rock (chiefly quartz) fills up the fracture.

In ascending order :—

Barakars.

1. Fine-grained sandstone and shales with shaly sandstone, dip 35° south-east.
2. Grey and variegated conchoidal shales.
3. *Coal*, with partings of shales, thickness 2′ 6″, dip 25° south-east.
4. Ripple-marked variegated sandstones.
5. Bituminous shales, with thin partings of coal, thickness 1′.

6. Shales.
7. Thick-bedded sandstone.
8. Shaly micaceous sandstone, 15° south-east.
9. Soft unevenly bedded calcareous sandstone, with gritty beds.
10. Shales and shaly sandstones.
11. Thick mass of false-bedded sandstone overlappng locally the series below.
12. Shales and banded sandstones, 5° south-east.

Fault.

Thick bed of sandstone.

Fault.

Beds are here much disturbed, and the dip changes gradually to east and north-east, and finally to north, at 38°, when we find in descending order :

Banded sandstones and shales.
Soft sandstones.

Fault.

Same beds as above :

1. Sandstone.
2. Grey conchoidal shales, bituminous, with banded micaceous and ripple-marked sandstones, dip 16° north, with—
   Grey clay shales (near junction with Balsotha nullah, dip 8° north-east.
   Banded micaceous sandstone.
3. Shales with COAL.

The whole series is, however, very much disturbed and shattered, and further on it appears that the same group of shales and sandstones are several times repeated.

The oblong expanse of Barakars mapped between the Balsotha nullah and the Pipra hills offers only a few exposures in the shallow nullahs. At several places south of the Pipra hill, fig. 1, Plate 5, and again near Maihewa, Barakar shales, with traces of leaves, are unmistakeable, but the remainder seems to be mostly fine-grained sandstone of Barakar type, traversed in several directions, as already described, by trap dykes, which have altered the neighbouring shales into a brick-like rock.

The faulted boundary with the Mahadevas is well seen south of Hargaon and of Gurmuti, where a fault-rock similar to the one described from the Garia nullah forms a high dividing ridge between the two groups.

B.—Morne River Sections.

14.—Section in the Morne Nullah between Kandia and Hadrai, Fig. 3, Plate 4.

3. *Talchirs.* In the Hadrai nullah they show the following section:—
   a, boulder-bed; *b*, irregular bed of marls and shales with boulders; *c*, thick beds of greenish fine-grained sandstone with lenticular masses of boulder-bed; *d*, silty-green boulder-bed; *e*, fine-grained sandstone with marly yellow and green shales, strike north 20° east to south 20° west, dip 10° to north-20°-west.
2. Sub-metamorphic conglomerate as described before, page 10.
1. Granite, with two hornblendic dykes.

Near the junction of the Morne with the Joba nullah the Talchirs are brought into direct contact with the Mahadevas by faulting. Tho beds are a good deal crumpled here by a succession of north-west to south-east faults, which in one or two places expose the purple and variegated coloured marls or clays of Panchet type below the Mahadevas which now dip 25° to 27° south-west.

15.—Sections of the Lundra Hills.

In the nullahs flowing from the Lundra hills, and joining either the Suknai or the Morne later on, we obtain very good sections through all the beds of Gondwána rocks.

In descending order:—

6. Mahadeva sandstone, forms a cap as it were on the top of the Panchet grits and clays, and with the latter is much shattered and traversed by local faults, difficult to trace. Near Lundra the lower beds (Panchets) appear again from below the Mahadevas and present a rolling dip, wherever seen, in the small nullahs intersecting this plain.
5. *Panchets.* *e.* Gritty sandstone with angular pebbles of metamorphics and hard ferruginous conglomerates consisting of angular fragments, some of considerable size.
   No exposure for some distance.
   d. Bluish silts, similar to (*b*), here and there variegated, with gritty masses and bands of clay iron ore.
   c. Gritty ferruginous shales.
   b. Silty beds, not unlike Talchirs in some respects, but densely red.
   a. Marly beds, splitting into rhomboidal pieces.

No exposure for some distance.

4. *Raniganj.* Fine-grained ferruginous grits.

No exposure seen for some distance.

3. *Barakars.* c. Shales and sandstones of Barakar type.

b. Coal-seam, 7′ thickness. Strike north 30° east to south 30° west: dip 9° north 30° west.

a. Sandstone, worn out in potholes.

2. *Talchirs.* Same succession as that seen in the Hadrai nullah. In the southernmost part of the Lundra sections the belt of Talchirs is only about a quarter of a mile in width; near Pandauli village it is nearly a mile wide, but forms now only a thin plastering over the metamorphics. North-east of Pandauli the Talchirs are worn away, and the underlying granite is exposed for some distance, forming an island as it were in the Talchirs.

1. Granite.

About a mile west of Lundra village the Panchet grits are again cut off by a north-west to south-east fault, which brings them into direct contact with the Barakars, which are well exposed in the Suknai nullah.

The sections shown in the Tabor and similar nullahs are greatly obscured by alluvial sands, and do not afford good material for observations. Similar clays and grits, as before described, are seen at intervals in the rivers and show a rolling dip, and in a red clay, containing lumps of hæmatite, *Vertebraria indica*, Royle, and *Glossopteris communis*, Fstm., were found; the bed corresponds exactly with bed 30 of the following section. Below Udhari I came suddenly on Barakars, of exactly the same type as seen in the neighbouring Suknai nullah; and west of Lundra, in the Suknai nullah itself (south-east of the Sarsera), a faulted boundary between the Barakars and Panchet grits is clearly shown.

16.—The section in the Suknai Nullah, between Sarsera and the junction with the Morne River.

In *descending* order as follows :—

Barakars.

Starting from the Morne river:

Dip 5° W. 20° N.	48. Bluish shales with faint impressions of leaves	
	47. Banded micaceous sandstone with coal markings	2′ 6″

46.	Shales with band of hæmatite	8'	
45.	Banded sandstone	6'	
44.	Blue shales	2'	
43.	Sandstone	4'	
42.	Shales	2'	
41.	Banded sandstone with carbonaceous markings	2'	
40.	Shales	1'	6"
39.	Banded micaceous sandstone	0'	4"
38.	Sandstone	4'	6"
37.	Conchoidal shales	5'	
36.	Shales and sandstone, not well shown, about	25'	
35.	Fine-grained yellowish sandstone	3'	
34.	Shales	0'	6"
33.	Red banded sandstone	3'	
32.	Shales with hæmatite band	6'	
31.	Grey fine-grained sandstone	1'	
30.	Clay shales with hæmatite band containing—*Vertebraria indica*, Royle, *Glossopteris communis*, Fstm.	9'	
29.	*Coal-seam*	0	4"
28.	Shales with *Glossopteris communis*, Fstm.	4'	
27.	Fine-grained micaceous sandstone with coal-markings; ripple-marked	1'	6"
26.	Conchoidal shales	2'	
25.	Fine-grained greyish yellow sandstone	4'	
24.	Sandstone and shales; the former micaceous with carbonaceous markings	25'	
23.	Blue shales	2'	
22.	Fine-grained sandstone with ripple-marks	10'	6"
21.	Blue shales.		
20.	Fine-grained micaceous sandstone with carbonaceous markings; purplish-coloured fine-grained sandstone with ripple-marks and grey sandstone	3'	
19.	Gritty sandstone	7'	
18.	Blue shales	1'	
17.	Banded micaceous sandstone with marks of coal overlaid by thin shales and bluish grits; the latter contains a thin parting of shales	8'	

16. Shales	...	1′	
15. Thick bed of sandstone ...	...	8′	
14. Conchoidal clay shales ...	...	2′	
13. Thin-bedded reddish sandstone overlaid by grits in thick beds, with intercalated thin beds of shales ...	...	12′	
12. Blue conchoidal shales ...	...	6′	
11. Greyish gritty sandstone ...	...	6′	
10. Bluish clay shales ...	...	4′	
9. Coal-seam	...	3′	6″
8. Conchoidal shales ...	...	4′	
7. Banded sandstone ...	...	1′	
6. Blue carbonaceous shales ...	...	4′	
5. Coal	...	0′	1″
4. Conchoidal shales ...	...	1′	4″
3. Reddish sandstone, gritty ...	...	2′	
2. Shales	...	3′	
1. Sandstone.			
TOTAL	...	211′	7″

Along the Suknai Nullah, south of Sarsera, I found in descending order :

II. Ranigang ? Soft white felspathic grits with pebble beds ; jointed.
Dip 70° W.-30°N.

I. Barakars.

Dip 50° W.-20°N. 29. Yellowish and blue conchoidal shales alternating with sandstone.

28. Dark shales alternating with ferruginous sandstone.

Dip 30° W. 27. Gritty earthy sandstone, micaceous, with carbonaceous markings and partings of hard ferruginous shales.

26. Micaceous clay shales.

25. Hard sandstones.

24. Carbonaceous shales.

23. Hard sandstone.

22. Carbonaceous shales.

21. Banded reddish micaceous sandstone, with partings of shales.

20. Grey conchoidal shales.

19. Hard fine-grained sandstone.

18. Dark shales.

17. *Coal-seam* 1

	16. Hard thin-bedded sandstone with micaceous bands.		
	15. Thin bed of hard blue shales.		
	14. Thin bed of hard sandstone.		
	13. Dark clay shales	4′	6″
	12. *Coal*, with shaly partings, thickness ...	7′	4″
	11. Reddish-banded micaceous sandstone.		
Dip 10° W. 20° N.	10. Dark-grey very hard clay.		
	9. Thin irregular bed of felspathic grit.		
	8. Banded shales; traces of leaves.		
	7. Grey clay shales, with papery-yellow shales, towards top densely red; traces of fossils.		
	6. Thin-bedded grits, towards base micaceous.		
	5. Friable grey shales.		
	4. Grits alternating with micaceous shaly sandstone.		
Dip 35° W. 20° N.	3. Banded shaly sandstones, traces of fossils.		
	2. Micaceous shaly sandstone, very carbonaceous.		
	1. Dark hard conchoidal shales.		

The section ends against Panchet beds along a fault.

The section in the Suknai nullah is evidently a continuous one, as is proved by the coal-seam; the 7′ 4″ coal-seam bed 12 of the last section is probably identical with the 7′ seam of the Lundra (Belia) section, and I identified this seam and nearly the whole group of beds in the following section.

17.—Section along the Nullah north-west of Ranka Khar.

Between the Mahadeva escarpment and the Morne river, I found the following beds in descending order:

No exposure for some distance; just below the Mahadevas are whitish grits and clays, which probably belong to *Panchets*.		
18. Shales with coal	3′	6″
17. Sandstone.		
16. Shales with a thin carbonaceous layer ...	1′	6″
15. Sandstone.		
14. Shales	0′	6″
13. *Coal*	2′	2″
12. Thin splitting shales.		
11. Sandstone with iron ore beds	14′	0″

	10. Shales with coal	... 10′ 0″
	9. Shales and banded sandstone ...	... 56′ 0″
	8. Shales.	
	No rock seen *in situ*.	
	7. *Coal-seam*	... 1′ 3″
	6. Shales	300′
	5. Hæmatite bed	
	4. Sandstone and shales ...	
	No rock seen *in situ* ...	... 120′ 0″
	3. Banded micaceous sandstone ...	... 3′ 0″
	2. Shales with a thin seam of coal	... 6′ 0″
Barakars.	1. Coarse-grained yellowish sandstone.	

18.—Section in the Budatand Nullah.

In the adjoining Budatand nullah I obtained nearly the same succession of rocks and coal-seams.

In descending order:

IV. Mahadevas.

III. Panchets ?	3. White gritty sandstone with strings of pebbles.	
	2. Hard brown micaceous sandstone.	
	1. Greenish sandstone with strings of pebbles.	
II. Ranigang.	4. Soft micaceous shales with fossils.	
	3. Shales with fossils— *Schizoneura gondwanensis*, Fstm. *Glossopteris angustifolia*, Bgt.	
	2. Soft light grey micaceous shales, marly, with traces of fossils.	
	1. Thick-bed of mealy felspathic sandstone.	
I. Barakars.		
Dip 20° north-west, but rolling considerably.	29. Shales and sandstone.	
	28. *Coal,* with shaly partings.	
	27. Thin-bedded sandstone and shales.	
	26. Conchoidal shales.	
	25. For some distance rocks *in situ* are only seen here and there higher up—	
	24. Carbonaceous shales, with partings of *coal*...	0′ 6″
	23. Hard sandstones with grey micaceous and bituminous shales alternating ...	43′ 0″
	22. Shales and sandstone alternating with banded shales on top	92′ 0″

21. Conchoidal shales with thin ferruginous partings and clayey shales at base	... 17′	0″
20. *Shaly coal*	... 0′	3″
19. Banded shales with micaceous sandstone	... 97′	0″
18. *Coal with shales*	... 17′	0″
17. Shales and sandstone with fossil leaves } 16. Sandstone }	17′	0″
15. Shaly coal	... 2′	0″
14. *Coal-seam*	... 3′	2″
13. Dark bluish shales	... 4′	0″
12. Sandstone in a thick bed ...	... 23′	0″
11. Thin-bedded sandstone and shales	... 42′	0″
10. Coaly shale with nodules of iron ore	... 0′	6″
9. Banded grey micaceous shales and sandstone	24′	0″
8. Shales	... 5′	0″
7. Hard sandstone	... 24′	0″
6. *Coal*	... 0′	9″
5. Sandstone and shales ...	... 15′	0″
4. *Coal*	... 0′	8″
3. Sandstone and shales ...	... 12′	0″
2. *Coal*	... 0′	8″
1. Hard fine-grained sandstone.		
TOTAL	... 440′	6″

19.—Section South of Manpur.

In the Morne river south of Manpur, I found Barakars well developed; the series is cut off by a fault about a mile south of Manpur village, and thrown against Mahadevas, which apparently dip below the Barakars.

In descending order I found:

I. Barakars:

Dip 15° N.	40. Shaly sandstone	0′	8″
	39. Grey shales with clunchy clays and sandstone with thin coal-seam 2″	6′	
	38. Same as 36.		
	37. *Coal*	0′	2″
	36. Dark-blue shales with clunchy ochre-coloured clays	1′	10
	35. Shales	2′	

34.	Coaly shale	3′	
33.	Same as 31	7′	
32.	*Coal-seam*	1′	4″
31.	Blue conchoidal shales with lenticular lumps of clay iron ore and bands of ferruginous sandstone	10′	
30.	Earthy bed gradually passing into clayey shales	1′	6″
29.	Dark shales, jointed	5′	
28.	*Coal-seam*	1	
27.	Shales and flaggy laminated sandstone, very fine-grained and white	4′	
26.	Not exposed 200′ in the bend of the Morne river. The following is the escarpment seen on the right bank, immediately below the village :—		
25.	Sandstone with partings of shales ...	39′	
24.	Blue shales	74′	
23.	Banded carbonaceous sandstone and shales...	14′	
22.	Carbonaceous shales	15′	
21.	*Coal-seam*	1′	2″
20.	Shales	5′	6″
19.	Carbonaceous sandstone	1′	
18.	Shales (with coal-seam 1″)	0′	10″
17.	Micaceous sandstone with carbonaceous markings	1′	6″
16.	*Coal*	7′	9″
15.	Shaly banded sandstone	15′	9″
14.	Shales	17′	6″
13.	*Coal*	1′	6″
12.	Sandstone and shales.		
11.	Shaly micaceous grey sandstone with fossil traces; partings of shales and ripple-marked.		
10.	Same as 7.		
9.	Layer of hæmatite.		
8.	Dark grey shales.		
7.	Grey shales and flaggy sandstone : some distance section hidden by river ...	3′	7″
6.	Thin-bedded sandstone with bed of shales ...	1′	8″
5.	Bluish-grey conchoidal shales	9′	6″
4.	Hæmatite bed	0′	3″

3. Hard ferruginous sandstone ...	...	1′	
No exposure.			
2. Grey shaly micaceous sandstone	...	3′	3″
1. Micaceous sandstone ...	...	3′	6″

20.—Section in the Morne near Parasdiha.

Between the junction of the Morne and the Budatand river and Parasdiha nullahs there is a succession of beds of Barakar type shattered by a series of parallel faults of north-20°-west and south-20°-east direction. I observed not less than four distinct faults in that portion of the section. The dip is very varying, and rolls from 5° north-west to about 5° east; but the section is too much covered by recent deposits to afford opportunities for study. Between the junction of the Parasdiha with the Morne river and the junction of the latter with the Satnachna, I obtained a very broken and faulted section of Raniganj beds as follows:—

Ascending:

Raniganj shales, &c.

Fault.

Raniganj.

1. Sandy micaceous soft shales with fossil traces	...	20′	
2. Sandstone	...	3′	6″
3. Grey shales containing—	...	0′	6″
Vertebraria indica, Royle.			
Glossopteris communis, Fstm.			
" *damudica*, "			
" *angustifolia*, Bgt.			
4. Thin-bedded sandstone	...	2′	8″
5. Grey flaggy and micaceous sandstones ...	...	1′	8″
6. Grey friable shales	...	1′	
7. Beds 5 and 6 alternating	...	6′	
8. Sandstone	...	1′	
9. Grey friable shales	...	0	2″
10. Sandstones	...	1′	7″
11. Flaggy sandstone and shales alternating ...	...	22′	
12. Grey, very friable shales	...	2′	6″
13. Flaggy sandstone	...	2′	9″
14. Sandstone	...	3′	
3 repetitions of this series by faulting.			
15. Blue shales, sandstone flags and shales ...	...	6′	

16.	Micaceous shaly sandstone	3′	1″
17.	Sandstone ripple-marked	0	6″
18.	Micaceous shaly sandstone and clays alternating ...	4′	
19.	Shaly coal, with partings of shales	1′	4″
20.	Shales	1′	4″
21.	Flaggy sandstone and shales alternating	3′	6″
22.	Shaly coal	0′	6″
23.	Sandstone flags and shales	18′	
24.	Thick bed of sandstone, ferruginous and capped by bed of hæmatite (2′)	2′	10″
25.	Shales with fossils	4′	8″
26.	Sandstone flags and shales	25′	
27.	Thick bed of sandstone	1′	
28.	Soft felspathic sandstone in irregular beds.		

Fault.

28. Sandstone.

Shales, &c.

At first the dip is 15° north-west, but it increases to 20° north-west within a short distance.

21.—Sections in the Suidud, Kubia, and Andherua Nullahs and the country westwards.

The sections along the Suidud, Kubia, and Andherua nullahs seem to be equally affected by the parallel faults noticed in the Morne river, for the Gondwánas there are completely shattered, and it is scarcely possible to identify the beds. The only point I could settle with any degree of certainty is, that the metamorphics south of these nullahs, near Dand Karua for instance, are covered by a considerable thickness of Talchir boulder-bed and shales; enormous boulders of lenticular shape are scattered throughout the silty matrix of the Talchirs, many of them being weathered out by sub-aerial denudation. Above Talchirs follow the remains of Barakar sandstones, shales, and coal-seams. The Barakar sandstone of the Suidud nullah, containing *Nöggerathiopsis hislopi*, Bunb., affords a very good illustration of erosion by water; large pot-holes and narrow gorges are formed by the rush of the water during the rainy season, as shown in the annexed drawing, fig. 3 :—

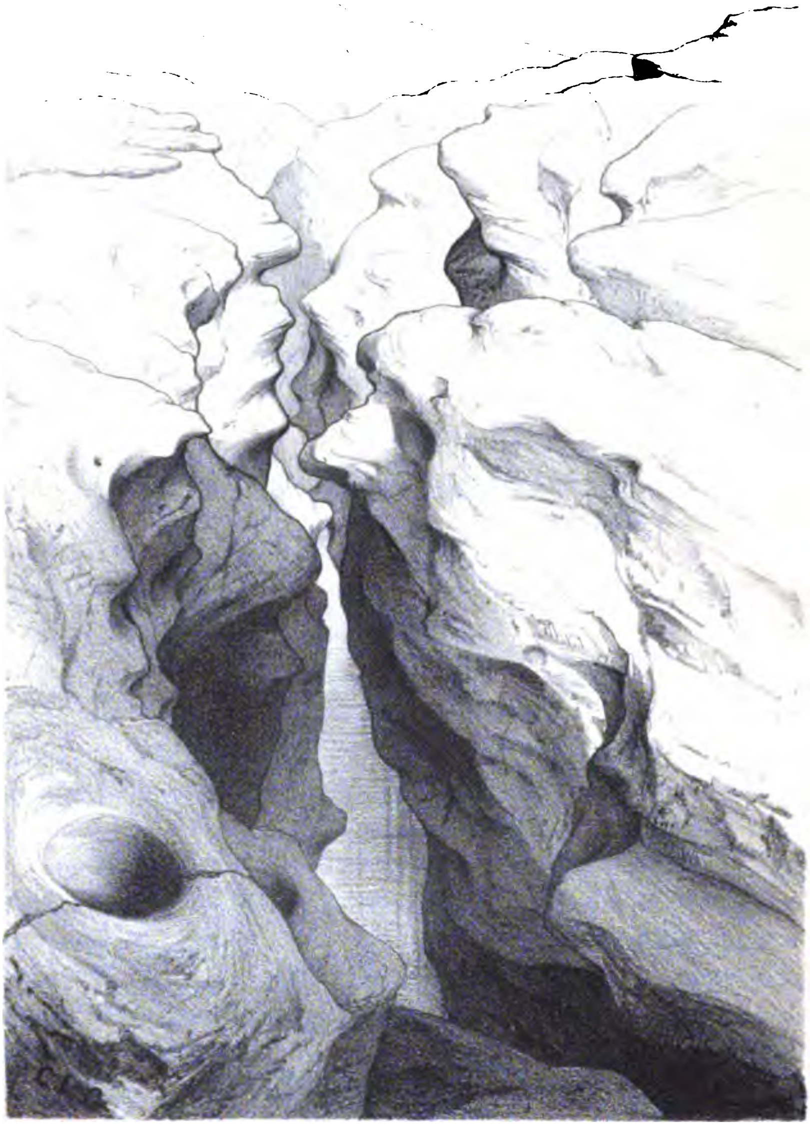


Fig. 3. Erosion in Barakar Sandstone of Suidud nullah.

Just beneath the Mahadevas of the Kathota hill a narrow strip of red sandstones crops out with red and purplish clays, which I include amongst the Panchet rocks on lithological grounds.

Similarly obscure are all the sections afforded in the Satnachna nullah; I could only obtain broken groups of rocks, and if they had not fortunately yielded fossils, it would have been very difficult to make out their relations.

The nullah cuts through the strata near Reonti, exposing them in two vertical cliffs of very nearly horizontal bedding. One of them due west of the village is as follows :—

Descending:

12.	Thinly-bedded grey shales and soft sandstones ...	25′	
11.	Bluish shales	0′	6″
10.	Micaceous sandstone flags with carbonaceous markings; they weather purplish	6′	
9.	Blue shales with layers of mica	1′	
8.	Conchoidal blue shales	4′	
7.	Same as 10	4′	1″
6.	Bluish shales	2′	
5.	Hard purplish sandstone flags	0′	6″
4.	Shales	0′	6″
3.	Hard purplish sandstone flags	1′	
2.	Clay shales	2′	
1.	Same as 10 and 7	1′	
		47′	7″

Similar is the vertical cliff north-west of Reonti village (southern village).

Descending:

11.	Soft calcareous sandstone	1′	6″
10.	Micaceous purplish-grey sandstone flags ...	1′	
9.	Marly, ochre-coloured shales	0′	10″
8.	Grey, very friable shales	0′	6″
7.	Leafy lignite, consisting entirely of fossil leaves ...	0′	1″
6.	Uneven bed of clunchy clay	0′	4″
5.	Same as 8	0′	9″

4. Grey marls, micaceous, alternating with yellowish-coloured soft sandstone; the beds of the latter are only about 1″ thick near top; towards base the divisions widen and sandstone predominates	...	3′	6″
3. Dark-grey bituminous shales ...	...		6″
2. Grey micaceous shaly sandstone with— *Glossopteris indica*, Schmp.	...	4′	
1. Grey shales, base not seen.			
TOTAL	...	13′	0″

About three miles further down the Satnachna nullah west of Dhonda village, I found another exposure, in descending order:

6. Fine marly yellowish-brown sandstone ...	...	1′	4″
5. Micaceous shales with carbonaceous markings	...	2′	6″
4. Marls	...	1′	10″
3. Nodular iron ore band with reddish shales, containing— ... ... *Glossopteris indica*, Schmp. ... " *communis*, Fstm. ...		0′	3″
2. Clay shales	...	0′	6″
1. Grey micaceous shaly sandstone with coaly markings, base not seen.			

There is very little doubt that these beds all belong to the Barakar group; both the lithological character as well as the palæontological evidence point in that direction.

Crossing over the level jungle country from Dhonda to Narola, I came successively across felspathic grits and ochre-coloured shales, which probably belong to the Raniganj series, as seen in the Morne river near Parasdiha, the beds of which section strike across that part of the country, but no absolute certainty can exist in the absence of a good section. The micaceous clay shales and red grits with purplish clays of Narola itself may in that case be Panchets, immediately underlying the Mahadevas. It is tolerably certain that all the groups of lower Gondwánas are represented in the patch between Noudiha and Ramkola, but the beds seen there are merely detached portions of rocks, surrounded on all sides by trap dykes and intrusive sheets, and in many places are quite altered by the trap flows into a brick-like mass. The shales with

sandstone beds of the Panphica nullah contain the following Barakar forms :—

Glossopteris damudica, Fstm.
„ *indica*.
„ *communis*.
Nœggerathiopsis hislopi, Bunb.

The shales and clays dipping below the scarp of the Tamor and Bendo hills contain *Glossopteris angustifolia*, Bgt., *Vertebraria indica*, Royle (branched form), and may probably belong to the Raniganj series, which they resemble in some respects. Near Namadháka[1] I obtained a nearly complete succession of the Gondwána series :—

I.—*Mahadevas* of the Kathota hill.

II.—*Barakar type* resting on the Talchirs, but nothing further was exposed between these and the—

III.—*Talchir silts* rest there on metamorphics (granite), containing many boulders of red Vindhyan quartzites. They are well seen in all the gullies coming down from the Kathota hill.

The great trap-sheet already mentioned has chiefly forced its way between beds of the Panchets and the Mahadevas, so that in nearly all the sections hereabouts, trap is met with in that horizon, though not always seen *in situ*.

C.—Mahan River Sections.

A very good section through nearly all beds of the Gondwánas is obtained between the Mahadevas of the Tamor scarp and the metamorphic series south of the Mahán river, fig. 3, Plate 5. I found in descending order :

6. The *Mahadeva sandstones* and grits form the wall-like escarpments of the Tamor and Dokrichana hills, which rise up to 2,758 feet, and which I have already described in my general chapter on Mahadevas, p. 19.

[1] Namadháka is a favourite encamping ground of the Gaewallas (herdsmen) of Singrowli, who take their cattle to the Sirguja jungles during the dry season for grazing purposes; it is south of Dand Karua and north-west of Pandari, just below the Mahadeva scarp, which stretches in a nearly north-south direction from near Pakni to Dand Karua, and which is called the Kathotha hills on the large survey maps.

5. *Panchets* are at least very probable below the Mahadevas in the neighbourhood of Garuatand, where yellowirh shaly clays are seen *in situ*, but the relations to the surrounding rocks are not clear enough to show them on the map.

4. *Raniganj* beds with numerous specimens of *Schizoneura gondwanensis*, Fstm., present in the Jokna nullah, but the boundary with the underlying Barakars cannot even be guessed at, as the nullah does not afford a continuous section. Similarly difficult is the adjoining section near Majurdaki, where the trap dyke has altered all the rocks, converting the whole into burnt brick-like masses.

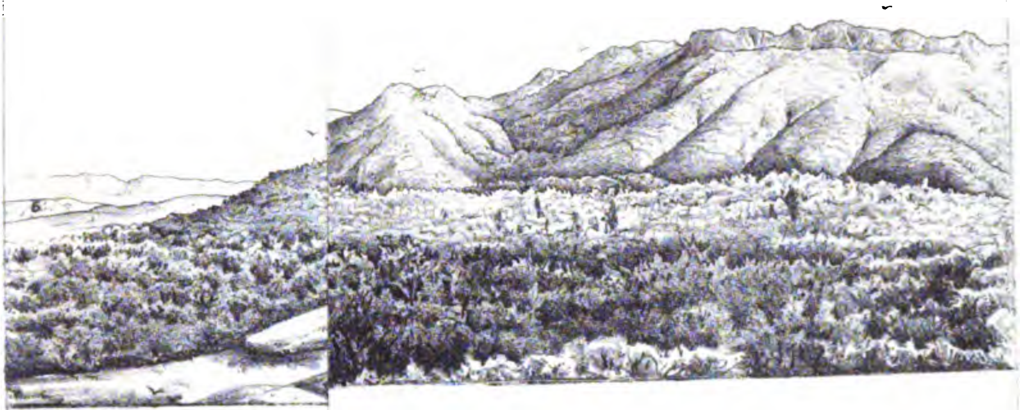
3. Barakars, containing *Vertebraria indica*, Royle., *Glossopteris indica*, Schmp.

The shales and sandstones near the trap have been altered into a glass-like slag in some places, and in many ways the trap has disturbed and shattered the adjoining rocks.

2. *Talchirs*. South of Ahirapara I found Talchir sandstones and silts with boulders of the usual yellowish-green colour resting on the metamorphic series. They form only a thin plastering over the older rocks, filling up hollows here and there, and thinning out and disappearing below the Barakars south-west of Chikni village.

A great trap dyke cuts through the area covered by Talchirs south of Ahirapara and altered the shales in some measure, so that it is not easy to distinguish them from the overlying Barakars.

1. *The Metamorphic series*.—Mica schist with veins of granite form the high ridge south of the Mahán river, and is a continuation of the range of metamorphics which stretches from near Tatapani in a south-west direction towards the Jilmilli field, separating the Bisrampur coal-field from my area. South-east of Majurdaki the mica schist immediately underlying the Talchirs contain numerous hornblendic veins, the whole dipping 55° to the north.



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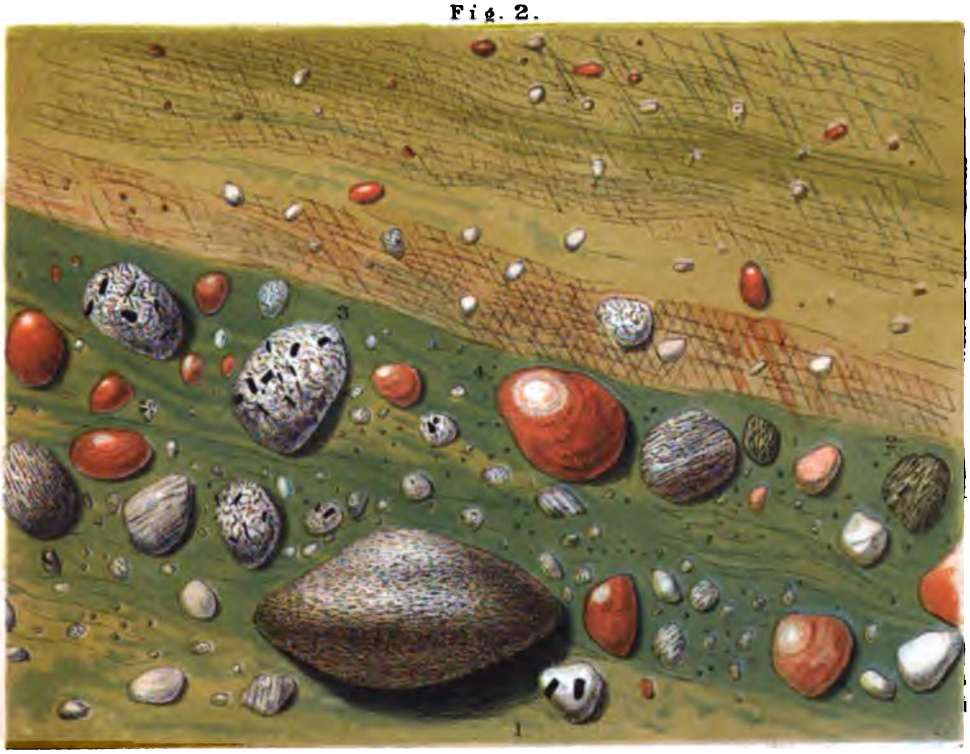
C. L. Griesbach del. & lith.

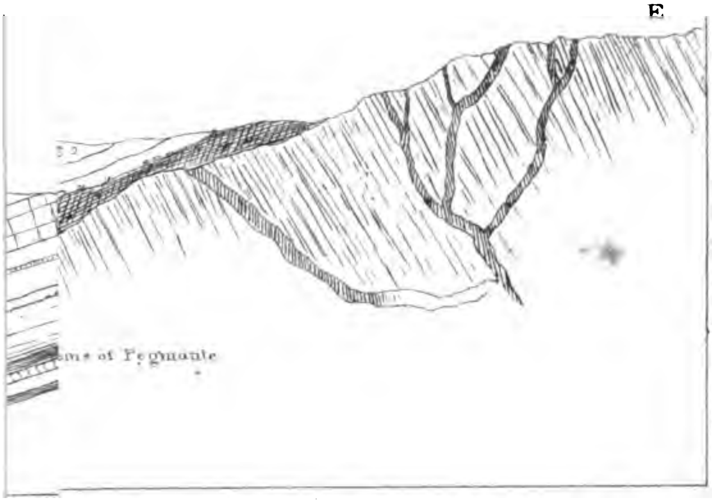
Fig. 1.

Fig. 2.



C. L. Griesbach. F. G. S. del. R. Mintern lith. Mintern Bros. imp.

Fig. 1. *Potholes in Talchir Sandstone. North of Mitgain.*
Fig. 2. *Talchir boulder-bed and shales, Southwest of Kandia.*
1. Gneiss. 2. Hornblendic Rock. 3. Tourmaline Granite. 4. Vindhian Quartzite.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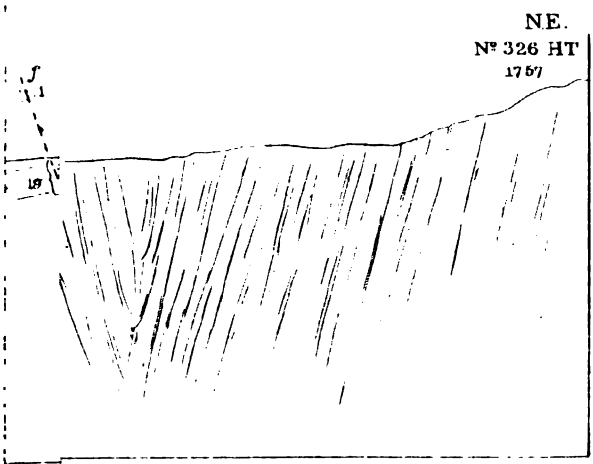
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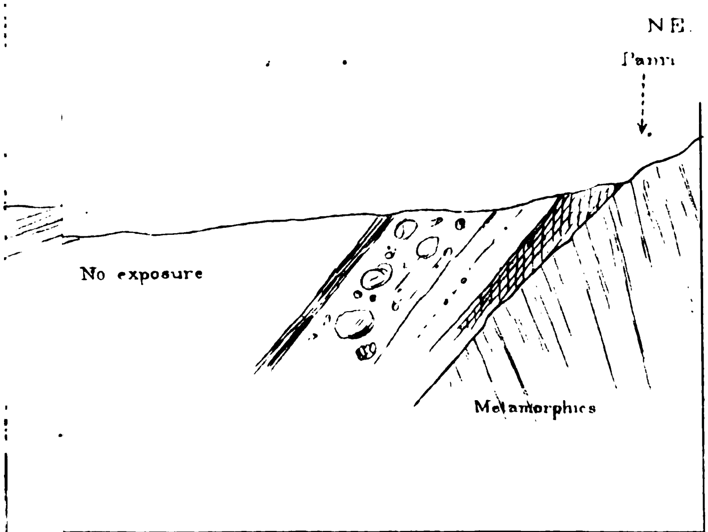
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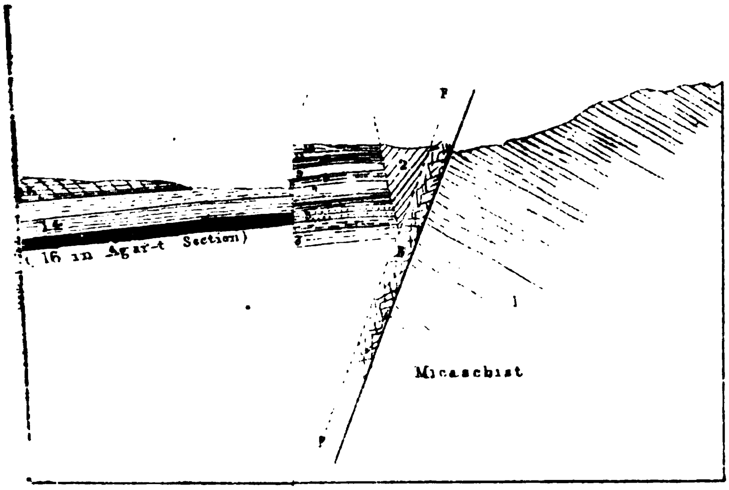

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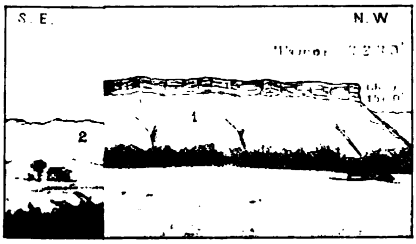
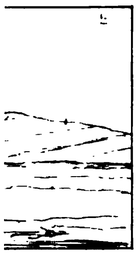
okars 14. to 16.

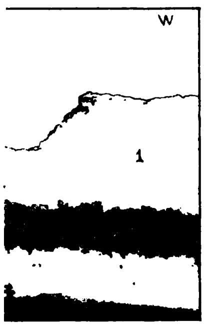
Nullah.

th 5. Panchet clays 6. *Mahadevas*



sheet of Trap (2)





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ART. 2.—*The Gneiss and Transition Rocks, and other Formations of the Nellore portion of the Carnatic, by* WILLIAM KING, B.A., *Deputy Superintendent (Madras), Geological Survey of India.*

PART I.

PART II.

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ILLUSTRATIONS.

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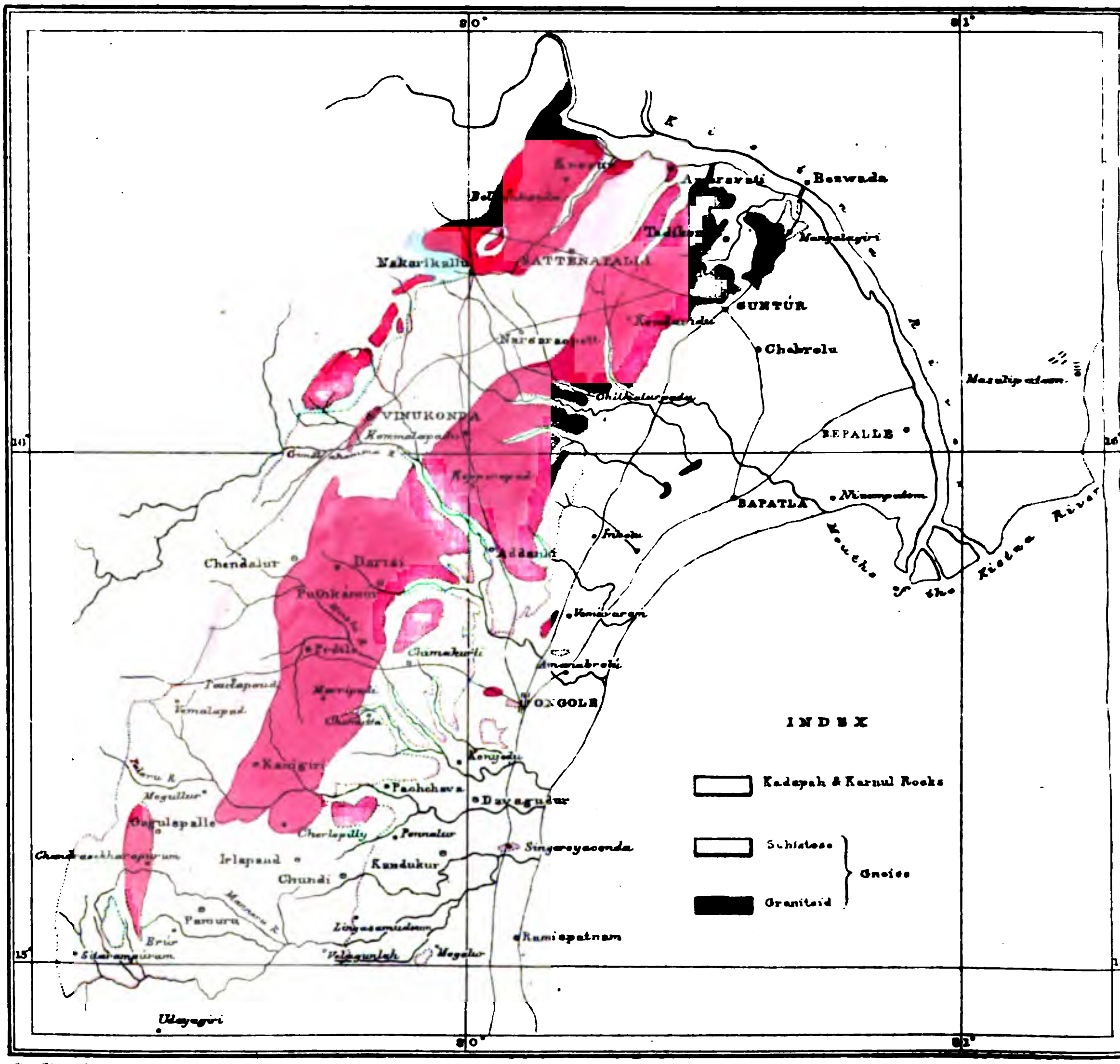

On Stone by Aminullah.

FIG 1. GENERAL DISTRIBUTION OF THE GRANITOID AND SCHISTOSE VARIETIES OF GNEISS.

MEMOIRS

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ON THE GEOLOGICAL STRUCTURE OF THE EASTERN COAST FROM LATITUDE 15° NORTHWARD TO MASULIPATAM,[1] *by* R. BRUCE FOOTE, F.G.S., *Geological Survey of India*.

CONTENTS.

CHAPTER I.—INTRODUCTORY.

The region to be described in these pages is included in four sheets of the Atlas of India, *viz.*, Nos. 75, 76, 95, and the extreme south-west corner of sheet 94. The topographical structure of the area dealt with is extremely simple. It is a mere inclined plane sloping gently

[1] Masulipatam is in latitude 16° 10′, twenty miles east of the Kistna: of the area under description that portion between the Kistna and the Godávari, on sheet 95 of the Indian Atlas, contains only deltaic alluvium, and has been omitted in the accompanying sketch map.

eastward from the foot of the Eastern Ghâts to the Bay of Bengal, and diversified only by scattered hills, or groups of hills, of no real importance geographically considered. The drainage is effected in the northern part by the Kistna river, in the southern and central parts by a number of small rivers running mostly in shallow valleys.

Fiscally the area is divided between the Kistna[1] and Nellore districts, the northern part belonging to the former, the southern to the latter collectorate.

Geological structure.

The geological structure of this area is almost as simple as the topographical. The western part of the area is occupied by a broad band or zone of ancient crystalline rocks belonging to the gneissic series, the eastern part is formed of the marine and fluviatile alluvia, while the intermediate part (speaking roughly) is occupied by a band of patches of sedimentary rocks of two ages, both older than the alluvial formations.

Rocks form three great zones.

Of these three bands the gneissic and the alluvial are by far the most important in point of extent, the former having its greatest width in the southern, the latter in the northern part of the area. The aggregate area of the other two series of rocks above alluded to, which represent the Lateritic and the Upper Gondwâna series, is small when compared with the gneissic and alluvial areas.

The geology of the Eastern Ghâts will not be touched upon in this memoir, as they have already been described in sufficient detail in Mr. King's memoir "on the Kadapa and Karnul rocks,"[2] of which the several ranges of mountains and hills forming the eastern mountain barrier in this part of the peninsula are composed.

[1] The Kistna district, as now constituted, includes the old collectorate of Guntúr and the southern part of the old Masulipatam collectorate, the northern taluqs of which were added to the Godâvari district.

[2] Memoirs of the Geological Survey of India, Vol. VIII. In this memoir Mr. King has embodied the results of the examination of the Kadapa and Karnul rocks by himself, the late Mr. Charles Æ. Oldham, and Mr. R. B. Foote.

Orographical features.

Of the detached mountains and hills which occur scattered at intervals over the inclined plane below the Ghâts, the following are most important, taking them from south-west to north-east:—

1. The Byrawndi Konda,[1] capped by an outlier of the Kadapa quartzites; from 2,000′ to 2,200′ high.
2. The Gogulapalli hills.
3. The Picherla Konda, 1,283′.
4. The Kanagiri (Kunnigherry) Drug hills, 1,500′ to 1,600′.
5. The Podile (Poudellah) hills, 2,183′.
6. The Chendalur hill, 1482′.
7. The Chimakurti hills, 2,091′.
8. The Koudavidu hills, 1,680′ (1,749′).

Of less importance geographically are the Chundi (Soondy) hills, in the south-eastern corner of the gneissic area, but they are of far greater geological interest than most of the loftier masses. Kotappa Konda, south of Narasaraopett, a noted place of pilgrimage, is a bold mountainous mass of granitoid gneiss, 1,588′ high. Lastly may be mentioned the Bellam Konda, another granite gneiss hill 1,500 or 1,600 feet high, remarkable for its fine shape, and crowned by an old native fort of great strength. A large number of hills, including the Kanagiri Drug hills and several others of considerable height, have been entirely omitted from the Atlas Sheet 76, which thus represents the Kanagiri taluq as flat, instead of very hilly.

Hydrography.

Of the rivers there is little to be said; their headwaters rise mostly in the east side of the Vellikondas. This is the case with the southern rivers, the Man-eru[2] (Mun Air), the Pal-eru (Pall Air), and the Musi-eru (Mooshee), and also with the Chilkalurpadu river in the northern part of the area. The Gundlakamma, which drains the central part of the area, rises beyond that range, in the Nalla-malla[3] (Black-mountains); while the Kistna touches the area only with its very lowest reaches.

[1] Konda is the Telugu word for mountain or hill.

[2] Eru (air) is Telugu for river.

[3] The western range of the Eastern Ghât barrier, the Vellikondas boing the eastern range.

Except the Kistna all these rivers receive their principal supply from the north-east monsoon rains; but the south-west monsoon rains appear to be heavier than in the latitude of Madras. The north-east monsoon is, on the contrary, lighter in this part of the peninsula than further to the south. Owing to the greater width of the peninsula, the westerly winds acquire a considerably higher temperature than at Madras, and begin to blow earlier in the season.

Geological formations.

The several geological formations occurring in the area under consideration may be conveniently grouped as follows, in descending order :—

Recent ...	7. Soils and subaërial deposits.	
	6. Alluvia, marine and fluviatile.	
	5. Lateritic, sand and gravels.	
Tertiary ...	4. Cuddalore (Rájahmundry) sandstones and conglomerates.	
Mesozoic ...	3. Upper Gondwána Series.	Pavulur and Chebrole sandstones.
		Vemávaram shales.
		Budaváda sandstones.
Azoic ...	2. Kadapa Series.	
	1. Gneissic, or Metamorphic Series, and intrusive rocks included in it.	

In describing these several formations, it will be best to take them according to their respective ages in ascending order.

Previous observers.

Before passing to their detailed description, it will, however, be well to give a few notes on the geological information that had been collected and published prior to the geological survey.

Dr. Heyne.

The earliest known geological notes on our area are those published by Dr. Heyne[1] in 1814, in the maps accompanying which he attempts to show roughly and partially the "geological situation" of the country. His geographical basis

[1] Tracts, historical and statistical, on India, by Benjamin Heyne, M.D., F.L.S., &c., &c. Naturalist on the Establishment of Fort St. George, London 1814. Of the two maps given, the first is far the more correct in its delineation of the rivers and mountains along the eastern coast.

being a very imperfect one detracts greatly from the value of his observations on the eastern coast. The greater part of the country he shows to be covered by cotton-soil, through which protrude hill ranges of syenite, basalt, gneiss, mica slate and clay slate.

He failed to recognize the geological distinction of age between the gneiss and overlying rocks.

The notes which have most reference to our area are those in Tract XIV, which gives "a short description of Buggelconda hill, near Innaconda, in the Guntur Circar," a hill which then and since has by many been held to be an extinct volcanic cone, in some way connected with the frequent earthquake shocks which then and now still agitate the Ongole country. He describes the highly hornblendic rock as a basalt, but in all other respects his description of the hill, in which he could trace no sign of volcanic action, is good. The earthquake shocks seem to have been both more frequent and more severe at the beginning of the century than of late years.

He disposes also of the idea that Innaconda (Vinukonda) hill is of volcanic origin.

In Tract IV he talks about minor ranges given off by the Eastern Ghâts, "which with very little interruption or variation of their constituents approach the eastern ocean not far from Ongole;" "to these ranges belong several remarkable hills, as the Chicola,[1] celebrated for the frequent earthquakes originating at it and spreading over the country; and the Ongole hill, which seems to influence the compass in an uncommon degree."

This statement is perfectly wrong as to the extension of the ranges eastward. No such ranges exist; the different hill ridges which are dotted about are quite unconnected, and in every case have a more or less northerly strike, as shown in the accompanying map; and owing to this the changes in petrological character are marked and frequent. Dr. Heyne's error is accountable for only by reason of his rapid rate of

[1] ? Chimakurti mountain.

travelling and by his having been misled by the very incorrect maps which alone then existed.

Of the several localities he mentions where copper ores exist, none appear to lie within the limits of this memoir: Agnigundala, or Agnicondalah (as he calls it), lies among the Kadapa rocks; Ganypittah, and probably also Terrapally in the Pannur (? Pámur) pergunnah, are among the small copper mines (now worked out) lying within the limits of sheet 77. These are described in the first of a series of papers on the mineral resources of Southern India published by Captain Newbold in the seventh volume of the Royal Asiatic Society's Journal, p. 151.

Dr. Benza.

Benza's "Notes, chiefly geological, of a journey through the Northern Circars," commence at Masulipatam beyond the Kistna, and treat entirely of the country to the northward. Newbold's "Notes, principally geological, across the Peninsula of Southern India, from Kistnapatam to Honawar,"[2] just skirt the southern edge of sheet 76 of the Indian Atlas; whilst the same author's notes on the road from Masulipatam to Goa[3] treat of the country between the coast and Hyderabad, north of the Kistna river.

Captain Newbold.

Mr. R. B. Foote.

The next reference is to be found in a paper by the author, on the distribution of stone implements in Southern India, read before the Geological Society of London in 1868.[4] The occurrence of implement-bearing gravels at considerable elevations in the neighbourhood of Pámur and at Nandanavanam, at foot of the northern end of the Vellakonda range, was mentioned, and the situation of the beds illustrated by a section comparing their position with that of laterite beds in the Madras area held to be of the same age. Some of these observations were republished in the author's memoir of the Geology of the Madras area.[5]

1 Mad. Jour. Lit. Sci., V, p. 43.
2 Journ. As. Soc., Bengal, 1845, XIV, p. 398.
3 Id. 1844, XIII, p. 984.
4 Quart. Journ., Geol. Soc., London, Vol. XXIV, 1868, p. 484.
5 Mem. Geol. Survey of India, Vol. X, p. 52.

Mr. C. Æ. Oldham.

In the annual report of the Geological Survey of India for 1868,[1] Dr. Oldham mentioned that Mr. C. Æ. Oldham, Deputy Superintendent, Geological Survey of India, had in that season recognized the occurrence of sandstones and shales of supposedly Rájmahál (Jurassic) age at Tangellamudi (Tunglamoody) near Bezwada, and at Inkolu and Razpudi on the Guntur-Ongole road. The striking lithological resemblance of these rocks to the Sripermatur beds near Madras was specially pointed out.

Mr. J. A. Boyle.

The latest publication containing geological information touching the area under notice is the Nellore District Manual,[2] the geological chapter of which, drawn up by the late Mr. J. A. Boyle, M. C. S. (in part from notes supplied by the late Mr. C. Æ. Oldham) refers, but only very briefly, to the geological formations in the northern part of the district. The shales and sandstones observed by Mr. C. Æ. Oldham at Razpudi, on the Guntur-Ongole road, and supposed by him to be of Rájmahál age (a supposition since confirmed by the discovery of numerous fossils), are mentioned.

CHAPTER II.—THE GNEISSIC OR METAMORPHIC SERIES.

The disposition of the various members of this oldest series of rocks in Southern India is, on the whole, less regular, and shows evidences of greater local disturbances within our area than in some of the more southerly districts, *e. g.*, the Madras (Chingleput), North and South Arcot, Salem, and Trichinopoly districts. In Madras and North and South Arcot especially there is a remarkable degree of parallelism between the strike of the great bands of gneiss and the coast line as at present constituted. In the southern half of our present area this parallelism may be detected, but only on a much smaller scale and over short distances,

[1] Published in the Records, Geol. Survey of India, Vol. II, 1869.

[2] Written in part and edited by the late Mr. Boswell, M.C.S., Collector of Nellore.

while in the northern it is entirely wanting, and the prevalent strike of the rocks is more nearly vertical to the present coast line than parallel to it. Petrologically there are many important differences between the gneissic rocks of our present area and those of the gneissic districts above alluded to. The facies of the northern gneissics is newer than that of the southern rocks; they have, on the whole, been less metamorphosed, but more disturbed by flexures, or else the way in which the disturbing forces affected them has left more distinct traces.

Differences from southern gneissic rocks.

The most striking petrological difference, and that which especially gives rise to the newer-looking facies of the northern gneissics, is the presence of numerous important beds of quartzite interstratified with the older-looking highly crystalline varieties. These quartzites are so singularly like the typical beds of Kadapa quartzites, occurring in the overlying Kadapa system in the Vellakondas and as outliers capping gneiss hills, such as the Bairawudi Konda and (outside the limits) the Udayaghiri and Korisi Konda, that they immediately suggested the idea of their being really members of the newer series, let down into their present positions by a series of remarkable parallel longitudinal faults. It was only after long-continued exploration of their relations that the conviction forced itself upon me that they were truly members of the gneissic system. My reasons for arriving at this conclusion will be stated further on.

Newer facies of northern gneiss.

Another point of difference is the greater development, in proportion to the general area, of highly micaceous and chloritic schists in the northern area, which for convenience I will call the Kistna-Nellore area.

A third point of difference may be observed in the large development of syenite-gneiss, of much more intensely hornblendic form than is common anywhere in the more southern parts alluded to.

Fourthly, may be mentioned the occurrence of considerable beds of mica schist highly charged with staurolite and kyanite crystals, a rock

as yet quite unknown among the southern gneissics. These minerals occur together in some of the beds, in others they are found separately.

Stratigraphical sub-division of gneissic series not practicable.

Much as the sub-division of this vast series of rocks would be desirable, if it could be carried out safely, the results of the survey would not in this case justify it at present, as the general stratigraphical relations of the principal groups of strata were not ascertained with sufficient certainty, owing partly to the disturbed and broken character of the strata, partly to the great extent and thickness of superficial deposits, and partly also the limited time which could be devoted to the work. In the absence of organic remains the sub-division of a great series of rocks must be based on well determined relations whether of infra or supra position of the several members of such series, and where such relations cannot be ascertained, as in the case in question, no sub-division should be attempted. A much closer survey than that now carried out, and laid down on better maps of much larger scale, would very likely supply many of the data now wanting to correlate the different rock groups (to use this term in a merely geographical sense).

At present as the relative positions of the principal groups remain to a great extent undetermined, it makes but little difference in what order they are considered, but for convenience in describing it may be as well to take them in a geographical order from south-west to north-east.

Petrological sub-division into schistose and granitoid areas or bands.

Although the gneissic rocks are not safely divisible into groups based on well-determined stratigraphical positions, they can easily be classed in two divisions, marked by great petrological differences. These two groups are the *Schistose* and the *Granitoid*. They occur distributed in several bands, of which four are principal ones and equally divided between the two groups. The bands which are shown in the annexed sketch map, *fig. 1*, follow, on the whole, a north-east-by-north to south-west-by-south direction; but the axes of the granitoid bands are by no means

everywhere coincident with the strike of the bedding, and appear to be axes of areas of extra metamorphism. The larger of the two principal granite gneiss bands occupies the centre of the gneissic area, and extends from a little south of the Paleru in Nellore district up to and beyond the Kistna. The smaller or western band extends from the Kistna south-westward to the Gundlakamma river close to Vinukonda, its western margin being overlaid by the Kadapa rocks; but it is exposed in various inliers which will be separately referred to further on.

The four granitoid areas, central and western.

Two other areas of granitoid gneiss of lesser but still considerable size occur, the one in the extreme south-west corner of the gneiss region described in these pages, the other pretty nearly in the centre of this region. The former may be conveniently called the Chandra Sekharapuram[1] area, after the large village situated near its centre, and the latter the Chimakurti area, after the Chimakurti mountain which forms it. Besides these larger granitoid areas there are several quite small ones scattered here and there through the schistose areas, but they are not very well defined and of no special importance; only a few of these will have to be mentioned separately.

Chandra Sekharapuram and Chimakurti areas.

The schistose rock-area is divided, except at its southern end, into two great bands, by the main band or area of the granitoid gneiss. The eastern of these bands, which extends northward from 15° 15′ to 16° north latitude, consists mainly of hornblendic varieties of gneiss; the western, on the contrary, consists mainly of micaceous beds and associated quartzites, but includes some hornblendic beds in its southern part beyond the Gundlakamma river. The eastern schistose band contains also a few quartzite beds, and in several detached groups a number of beds of magnetic iron, some of which are of considerable richness and possibly of future importance economically.

The schistose area and bands.

[1] Chendra Shakrapoorum of sheet 76.

The boundaries between the two rock varieties are in every case obscure; where seen in close proximity, they pass into each other by hardly perceptible gradation, as might be expected of rocks of which some parts have from various and as yet unexplained causes undergone more extreme metamorphism than others. Within the granitoid areas, different beds have undergone varying degrees of metamorphism; and in some, indeed in many cases, this would appear to have been influenced by the texture of the rock, for it would seem very probable that the metamorphism has advanced directly in proportion to the coarseness of the original materials of which the old sedimentary rock was composed. This suggests the idea that these areas of extra, or apparently extra, metamorphism may have been caused in part, if not entirely, by the peculiar distribution of the coarser sedimentary materials of which these rocks were originally formed. The peculiarity of such distribution must have depended on the strength and direction of the currents then in action, and on the nature of the materials yielded by the yet older rocks then undergoing denudation. The hypothesis that the granitoid areas coincide with areas of deposition of coarse sediments, helps to explain the difficulties (which would otherwise be hard to deal with) in accounting for the occurrence of small isolated patches of granitoid rocks among the true schists, and similarly of schistose beds within the granitoid areas.

Boundaries of areas ill defined.

1.—The Schistose Areas.

Beginning, as before proposed, in the south-west corner of our area, we find at foot of the Vellakonda mountains, in latitude 15° north, a very wild rugged tract of country made up of mica schists, with a few beds of quartzite.

To the west this mica schist appears to be underlaid by the newer Kadapa rocks; but this appearance is due to a great line of fault by which the younger rocks have been thrown down, so that they abut against the gneissic beds.

The great Vellakonda fault.

This fault, however, does not everywhere form the boundary between the gneiss and the Kadapa rocks in this corner, as after following the fault for about 25 miles northward, the boundary line diverges from it and follows the eastern side of a patch of the basement beds of the Kadapa series, which here rests on the gneissic mica schist.[1] Further north, however, the faulted boundary recurs and extends with only one break up to the Kistna.

Gotlabailu mica schists.

The most westerly set of mica schist beds, which may be called the Gotlabailu (Gotlabyloo) series, forms several low but very rough jungle-covered ridges which coincide with the strike of the bedding. The quartzite beds above referred to run in a line nearly north and south through the centre of the mica schist area. The quartzite becomes in places so micaceous as to pass into true mica schists. These beds may be conveniently called the Sitárámpuram (Sheetarampoorum) quartzites.

Sitárámpuram quartzites.

Bairawudi Konda schist series.

The second set of mica schists forms the base of the Bairawudi Konda, a considerable mountain mass capped by the largest and most important outlier of the Kadapa rocks eastward of the Vellakonda mountains. The mica schists are well seen along its flanks, and the unconformability of the two rock series is very conspicuously displayed in the great ravine at the south end of the mountain, after which the series may be suitably named the Bairawudi Konda schist series. The prevalent colours of these schists are dark greenish-grey and a dull dirty yellowish-brown.

Quartz veins of small but irregular thickness are extremely numerous here as in most mica schists, and the surface is extensively and thickly covered with quartz debris, which frequently hides the rocks over a large extent of ground.

[1] The fault is apparently continuous along the base of the Vellakondas, the western side of the patch of basement beds being itself faulted unconformably against younger beds of the same series.

A couple of miles eastward of the Bairawudi Konda the mica schists dip under a narrow band of quartzites (the Chennampalle quartzites) separating them from the most westerly band of granitoid gneiss which I have above called the Chandra Sekharapuram band. Eastward of this gneiss again lies another set of quartzites which have a westerly dip, and appear to form with the former a synclinal basin, including the granitoid rocks. East of this second quartzite band comes in an extensive series of schistose beds, mainly micaceous, which may reasonably be regarded as the representatives of the great mica schist series forming the base of the Bairawudi Konda. These eastern mica schists occupy a wide valley in which lies the village of Irur (Eroor), after which this valley and the schist series may be conveniently called. The surface of the schists is greatly hidden by large spreads of cotton-soil in various parts of the valley. To the east this valley is bounded by an important band of quartzites, which may be traced some 20 miles northward from the southern boundary of our area, and which rises into ridges of considerable height (500′-600′) near Irur (Eroor) and near Gogulápalle.

Chennampalle quartzites.

Mica schists of Irur valley.

Gogulápalle quartzite ridge.

This quartzite ridge, which I will designate as the Gogulápalle (Gogoolpully) ridges, represents very probably the Sitárámpuram quartzite ridge first referred to, towards which it dips. It is in its turn underlaid by another schistose series which includes locally several other sets of quartzite beds. To this schistose series the name of Pámur series may be appropriately given from the important village of that name lying some four miles north-east of Irur. The stratigraphical relation of the several quartzite ridges and schist valleys just named seems clear, within the region occupied by the head waters of the Man-eru; but northward of Gogulápalle and eastward of Pámur, the extension of these several rock series cannot be followed with any certainty. The continuity of the formations is interrupted, mainly by great

Pámur schistose series and area.

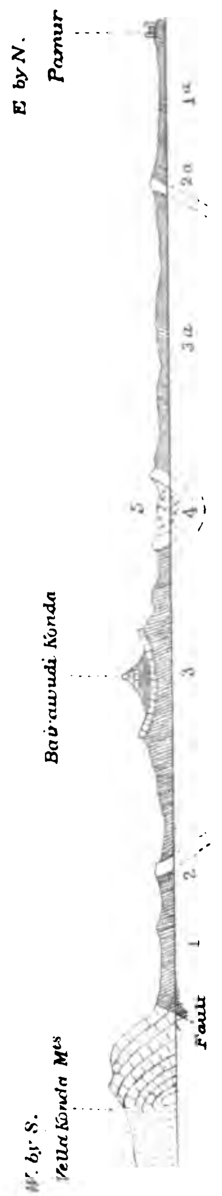

Fig. 2. Section from near Sitarampuram to Pamur; 24 miles.

accumulations of soil and vein quartz debris furnished by the mica schists. Great and sudden changes of strike appear to indicate important faults, though none were actually traced, because the rocks are so insufficiently exposed. The annexed diagrammatic section illustrates the stratigraphy of the gneissic rocks just described between Pámur and the foot of the Vellakonda range.

Pámur Section.

Eastward of Pámur hornblendic schists and true gneiss become very common, and mica schists less and less common, as you proceed eastwards, and the strike of the beds varies greatly owing to great bends and contortions. The contortions are specially well seen in the quartzite ridges among the Chundi (Soondy) hills and the Picherla Konda. North of the Chundi hills the strike of the beds is generally pretty constant and not interrupted by many contortions. The prevalent direction is north-easterly.

The micaceous schists in this region are, as a rule, much less micaceous than those west of Pámur, and they often pass into true gneiss or into quartzite.

Picherla Konda quartzites.

The most important set of quartzites in this region are those forming the Picherla Konda, a bold ridge of hills rising on the crest of the water-shed between the Man-eru and the Pal-eru. The main ridge forms the

east side of an acute synclinal fold, the terminal curve of which takes place at the southern end of the ridge, close to the trigonometrical station which crowns the highest summit. The synclinal opens to the north, and the ridges die away and disappear under superficial accumulations near the southern limit of the eastern granitoid gneiss band, which the quartzite beds appear to underlie.

No connection was traced between these Picherla Konda beds and any of the other quartzites. Their position relatively to the great eastern granitoid gneiss band, which they have every appearance of underlying, suggests the possibility (if not the probability) of their representing the quartzites underlying the Chandra Sekharapuram granitoid band.

Chundi hill quartzites.

Of the quartzites in the Chundi hills only one set requires special notice because of their extent. These form the Chundi trigonometrical station hill, immediately north of the village of Chundi. Here as well as in the Picherla Konda the beds are many hundred feet in thickness.

Ianekotai quartzites.

Another set of quartzites shows in the flat jungly country south-west of the Chundi hill group. They form two small but striking hills, one at Ianekotai (Ianacotah), the other at Iawarpalle. They are of much smaller thickness than the Chundi hill beds, but like them rest upon a great series of highly hornblendic schists, and it is very probable they both occupy the same horizon in the general succession of the gneissic rocks.

Staurolite beds of Mala Konda, &c.

Overlying the Chundi quartzites are mica schists which in many parts are very thickly crowded with prisms of staurolite (staurotide), in others again with crystalline masses of pale blue kyanite (disthene), or with both minerals mixed up confusedly. The mica schist charged with both these minerals is best seen on the Mala Konda, the south-western extremity of the Chundi hills. It there rises into a considerable hill with a craggy summit, crowned with a small Vishnu temple, one of the most frequented

shrines in that region. It is one of the most picturesque spots in the northern half of the Nellore district, some of the great masses of mica schist having fallen over and lying about in wild confusion interspersed with trees and buildings. The great numbers of crystals which crowd the rock give it a very rough surface.

The staurolite crystals are generally of large size, 2 to 3 inches long by 1¼ to 1¾ in width, but both larger and smaller sizes are met with. The large crystals are almost invariably of coarse texture and much covered with a film of mica which conceals the true colour. Some of the smaller crystals have a fair amount of lustre, and are of dull blackish-red or reddish-brown colour. Twin crystals forming true crosses and diagonal (St. Andrew's) crosses are common, especially at the Malakonda, but not often of good shape. Along the west side of the Malakonda ridge and also at Kotapalle, two and a half miles north-west-by-north of Chundi, the surface is thickly strewn with the prisms weathered out. In various damp spots the weathered crystals get covered with a shining ferruginous coating and pass gradually into a species of lateritic concretion, as do also some richly ferruginous garnets in other parts of the gneiss country. The kyanite was seen only in the Malakonda beds, in which the crystalline masses are nearly as numerous as the staurolite prisms.

Of Kotapalle.

The staurolite crystals were met with in two other localities, one in the ridge forming the extreme south point of the Chundi hills westward of Lingasamudram village, the other, a low hill, about two miles south-west of Picherlakonda Trigonometrical station. In the former case, the crystals are rather small and not numerous; in the latter they are large and very numerous, and the general appearance of the rock agrees with that occurring at Kottapalle near Chundi, except in the absence of kyanite.

Of Lingasamudram.

Near Picherla Konda.

Several of the quartzitic beds in the Chundi hills are locally rich in tourmaline crystals. In a thin bed on the crest of the ridge west of Chundi, the rather

Tourmaline in quartzite.

micaceous quartzite is crammed with prisms, mostly minute, of black tourmaline. This is well seen where the ridge is crossed by the footpath leading direct from Chundi to Ramalingapuram. A similar bed occurs on the east flank of the hill west of Lingasamudram, close to the staurolite bed already referred to above. Close by another bed contains very large coarse crystals of equally black tourmaline, several large lumps of which were brought to me by a native under the impression it was coal.

Magnetic iron and hæmatite schist beds.

Among the most noteworthy members of the schistose group are the ferruginous beds; these are of two kinds, the magnetic iron beds and the hæmatite schist beds. The former, though not so rich as the great magnetite beds in Salem district, &c., are yet deserving of much attention, both stratigraphically and industrially; but the remarks to be made on their industrial importance will be reserved for the chapter treating on the economically important geological features. Of the hæmatite schists only one example was met with which will be referred to more fully further on. All the more important magnetic iron beds of the gneissic series belong to the eastern schistose band; but several are found occurring in outliers away from the main band, the intervening space being occupied by the newer sedimentary formations. They occur in two principal groups which I propose to call the Ongole and the Gundlakamma groups respectively, the former occurring near the town of Ongole, and the latter lying entirely in the lower part of the valley of the Gundlakamma river. Only one small bed was met with, which from its position could not be assigned to these groups; this occurs in a small inlier of gneiss on the left bank of the Man-eru, 3 miles south-west of Singuraza Konda travellers' bungalow on the great north trunk road. This magnetite bed forms a low rocky ridge rising out of the alluvium and lateritic shingle, and known locally as the Shinampudi Tippa. The bed is of considerable thickness, about three-quarters of a mile long, and moderately rich in iron.

Two groups of magnetic iron beds, the Ongole and the Gundlakamma groups.

Shinampudi bed.

Fifteen miles to the north of Shinampudi (Sanampoody) Tippa lie the most southerly members of the Ongole group of magnetic iron beds, consisting of four beds forming a strong anticlinal curve round and through the mass of the Konijedu (Conjàdoo) hills. The other members are the magnetite beds which form the main mass of the Ongole hills, and those forming the Parnametta hill, 4 miles north-west-by-west of Ongole. A glance at the map will show that, although separated from each other by considerable distances, the position of these three sets, or sub-groups, of magnetite beds, relatively to each other, is such as inevitably to suggest a direct connection between two of them, if not between all three. The strong petrological resemblance of the beds themselves and of the intermediate gneissic beds, as well as the near correspondence in number of beds, leads me to regard the Parnametta and Ongole beds as merely the extensions of the great Konijedu curve, the Parnametta beds corresponding with the northern, the Ongole with the north-eastern arm of the great anticlinal curve. A very trifling bend in the strike of the two arms of the curve would cause the extension of the beds, now masked by overlying lateritic and alluvial deposits, to coincide with the Parnametta and Ongole beds. It is, however, possible that the Ongole and Parnametta beds may form the arms of another curve (parallel to the Konijedu curve), the apex of which is hidden by the newer formations. I regard the first assumption as the more probable, and the more so as the Parnametta beds resemble the Konijedu beds more closely than the Ongole beds.

Ongole group of iron beds.

Konijedu bed.

The Konijedu group consists of four principal beds, of which the two upper ones are the richest. They are fairly rich as compared with the most important of the great magnetite beds in Salem district. The same may be said of the Ongole and Parnametta beds; they do not, however, appear to have been worked for iron ores, though largely used as rough building stone.

Konijedu iron beds.

The number of beds at Ongole is five principal ones, though seven might be counted if two which contain thin gneissic partings be regarded as four several beds.

Ongole iron beds.

The dip of the beds is from 40° to 55° south-south-easterly. As at Konijedu, the southern beds are the richest; they form the low ridge abutting on the high road close to the shrine and Math of some Pír of great local sanctity. The northern beds, which form the Trigonometrical station hill, are much less rich in iron. The Math hill beds are fairly typical magnetic iron beds, in which the magnetite occurs in discontinuous granular laminæ, interstratified between granular quartz laminæ, which are generally stained of a reddish or brownish colour where weathering has taken place to any extent. The unweathered rock is generally of a purplish or blackish-grey colour. The non-ferruginous bands separating the different magnetite beds both here and at Konijedu consist of a quartzo-felspathic granite gneiss, in some places coarsely granitoid in texture, but showing in others a texture resembling woody fibre, which might for brevity be described as "xyloid."

The Parnametta beds are four or five in number, have a westerly dip of about 60°, and show signs of having undergone much greater disturbance than the other sets of beds to the east and south. A number of rude cleavage planes render the interpretation of the stratification by no means easy or satisfactory.

Parnametta iron beds.

The Gundlakamma group of magnetite beds consists of four sub-groups, separated from each other, except in one case, by considerable distances, and showing no features of special resemblance on which to base any comparison between them. Still their general position, with reference to the adjoining members of the gneissic series and to the general strike of the bedding in that tract of country, indicates that they may very probably belong to one and the same horizon, though now broken into detached portions; it is quite probable too that they may be representatives of the Ongole group.

Gundlakamma group of iron beds.

Burapalle beds.

Of the four sub-groups, the southernmost, which lies close to the village of Burapalle, is the most important by far. Two thick beds, separated by a rather granitoid gneiss, here form a great part of a considerable hill. They appear to be connected with the magnetite beds in the Tammaveram hill, 2 miles to the north-north-west; but thick soil and talus accumulations cover the outcrops of the beds for about a mile intermediately. Three beds are here seen. They are violently contorted, and appear to be cut off by a fault to the east; to the west and north they disappear under the alluvial deposits of the river valley.

Manikesvaram beds.

About a mile and a half to the north-north-west is another magnetic iron bed which forms a small but very rocky hill just west of the village of Manikesvaram (Maunikeswarum). This bed, which forms a very acute bend at the north end of the hill, is exposed for little more than a mile in length, its ends disappearing under the soil. It is underlaid by massive banded hornblendic gneiss, and apparently overlaid by pink granitoid gneiss, but the contact with the latter is not seen, there being a considerable space between them in which no rock is exposed. This forms the second sub-group of the Gundlakamma group.

Singirikonda beds.

The third sub-group consists of five beds, which form the main ridges of two hills a couple of miles north of Addanki. Three of these, which are moderately rich in parts only, form the Singirikonda, a hill rising about 400 feet on the east side of the great north trunk road. The beds dip east at a high angle. In the lower hill west of the road are apparently two beds, but their lie is very obscure, and they may possibly represent but one bed crumpled into an acute synclinal trough.

Vemparala beds.

About 4 miles north-west-by-north of the Singirikonda group lies another small group of four rather unimportant beds; their relations to each other are not clear, the two northern beds running at right angles to the strike of the two southern ones. If, as the map suggests, they are parts of a great curve,

the two northern ones have probably been inverted by faulting of the strata. These beds form the Vemparala group.

To the eastward of the Gundlakamma magnetite beds, the band of schistose gneiss is greatly encroached upon by the granitoid gneiss band, leaving but a very narrow belt of the former between the granitoid band and the younger sedimentary rocks fringing the coast. The schists occupying this narrow belt are mainly hornblendic, but are of no special interest.

Two or three rather poor beds of magnetic iron occur within the limits of the granite gneiss band west of the Gundlakamma, to the east of Purimetla (Pooreemetta) tank, about 4 miles west of the last-mentioned set of beds near Vemparala. But for their exceptional position, these beds offer nothing of any interest.

Hæmatite schist near Chundi.

It was mentioned above (page 17) that one instance had been noted of the occurrence of hæmatitic schist in the gneissic region. This was seen in the Chundi hills, west of the village of Polenane Cheruvu, where several hæmatitic beds occur associated with a great thickness of micaceous clay and flaggy schists. One or two of the hæmatitic beds are rich, the remainder poor and of no importance. Their northern and southern extensions are lost sight of in the extensive low jungle which covers all the ridges in that quarter.

Chimakurti quartzites.

Before concluding our references to the eastern schistose band, we must consider three other sets of quartzite beds which belong to it. Two of these are associated with the Chimakurti outlier of trappoid, or intensely hornblendic, granite gneiss above referred to (page 10), and lap round it as if underlying it conformably and forming the walls of a surrounding synclinal ellipse. Of the real infra-position of these quartzites to the hornblendic beds, there can be no doubt on the western side of the Chimakurti hills, but on the south-eastern and northern sides the quartzites are not seen, but are either wanting or obscured by talus deposits. They show well for about 4 miles on the eastern side of the ellipse, but are inverted at

the southern extremity of the hilly ridge they there form. If continuous, these beds would have to be considered as of one and the same set.

Massávaram quartzites.

The third bed is seen in a tiny inlier in the alluvium of the Man-eru, 5 miles south of Kandukur. It forms but a small rocky hillock abutting on the bund of the great Massávaram tank, but is worthy of special notice, as being perfectly different from the ordinary quartzites of this region. The rock is a very glassy large-grained quartzite of delicate pale aquamarine-green, banded with deep purple. The purple bands occur in discontinuous laminæ, looking much like so many stains. If cut and polished it would be a stone of quite extraordinary beauty for decorative purposes. The hill is formed by a boss on the outcrop of a bed which has a steep dip to the east-by-south. Another mass of quartzite of glassy texture and pale aquamarine-green was noted in the jungle near Balla Venkatapur, on the west side of the Picherlakonda quartzite curve.

Talcose and chloritic schists.

Among the less common forms of schistose gneiss to be mentioned are the talcose and chloritic beds, which occur in various parts of the schistose area, but especially in the western schistose band. Nowhere, however, do they form an important feature. The greatest development of the talcose rocks is to be seen near the head waters of the Mushi river, immediately east of the boundary of the Kadapa rocks, and at the villages of Gazulapalle (Gazoolapully), Chinna Managundum, and Soutapalem. They occur in considerable quantity also to the north of the Musi river, between Chendalur hill and the Kadapa boundary. Talcose rocks were also observed to the west of Vinnukonda, near the villages of Bharatapuram and Naddigudda. The rocks are generally talcose schists. A coarse gritty variety of talcose gneiss occurs along the boundary of the Kadapa basin near Chittapuram to the northward of Vinnukonda.

Chloritic schists are found chiefly in the southern part of the schistose area, near the villages of Narapareddypully and Malareddypully, 8 or 9 miles south-west-by-south of Kanigiri. They here occupy the place that should be filled by the extension of the western branch of the

great quartzite series forming the Picherlakonda (page 14). The quartzites have disappeared apparently by change of mineral character, a phenomenon they often show, but in this case the probable connection with the chloritic schists cannot be traced owing to the enormous amount of quartz debris which covers the entire surface of the country hereabout. The immense quantity of this quartz debris, which is derived from the small quartz veins traversing the various schists, shows how great the denudation the schists have undergone in recent times. The chloritic rocks are exposed only in a few well-sections.

Rocks masked by debris of vein quartz.

Crystalline limestones are developed to a very small extent in the Nellore-Kistna gneissic area, and were seen but in a few places. Of those noted, the most important occurs at a little distance south-west of Chundi. It occurs on the western slope of the ridge west of Chundi valley, where crossed by the path to Ramalingapuram. The limestone, which is of grey colour speckled with small scales of mica, and of saccharoid texture, forms a bed 4 to 5 feet in thickness. The outcrop was not traced to any great distance, owing to its being covered by scrub jungle and talus of the higher lying quartzite beds. This limestone contains slight traces of copper in the shape of copper pyrites.

Crystalline limestones.

Numerous fragments of crystalline limestone of pale grey and pink colours were observed on the high ground about 3 miles north-east of Pedda Allavalapad, but the bed whence they were derived was not seen. Probably it is hidden by the extensive spread of cotton soil which there covers the face of the country. This limestone contains numerous crystals of black tourmaline and some small irregular inclusions of dirty white weathered felspar. Precisely similar tourmaline crystals are very common in numerous small irregular granite veins which traverse the hornblendic granite gneiss near by.

Near Pedda Allavalapad.

A bed of sub-crystalline whitish limestone occurs east of the village of Pedda Arikatla, 8 miles north-by-east of Kanigiri. But little is seen of his bed owing to a

Near Pedda Arikatla.

thick deposit of red soil which overlies it. Traces of a similar limestone were also noted to the south-west and east of Irslagundum, a village about 2 miles to the west-by-north. Both these beds belong to the western schistose band.

At Punugodu.

A small but very remarkable bed of impure crystalline limestone occurs at Punugodu (Poonoogodoo), on the right bank of the small Makeru river 5 miles east-by-north of Kanigiri. The bed forms an anticlinal semicircular curve about 200 yards in length, the dip trending from west to nearly south-east, and the bed being from 6 to perhaps 10 feet in thickness. In the purer parts of the bed the limestone is of bluish or greenish-white colour, but with it are interbedded many thick chert-like laminæ of a reddish mineral much resembling calderite (massive garnet). In parts of the bed these laminæ greatly exceed the limestone in quantity,

With cleavelandite and epidote.

and in others, especially near the base, the calcareous laminæ disappear altogether. At the base the bed is very epidotic—epidote forming to a great extent the laminæ between the highly silicious limestone. Rather higher up the chert-like laminæ consist of a mixture of epidote (approaching to pistacite) and calderite. Near the southern end of the curve some of the partings have a perfectly granitoid texture, and look much like small granite veins injected between the planes of deposition; probably they are merely results of metamorphism. The two ends of the curve terminate abruptly, as if faulted against the adjoining granitoid gneiss; but the junction is too obscure to speak with certainty as to the faults. No eastward extension of the beds can be made out either in the bed of the river or on its left bank. A couple of miles down the river I observed several large blocks of epidotic rock, doubtfully *in situ*, in the bed of the river close to the right bank opposite Patha Garlapetta. In texture and lustre the epidotic mass strongly resembled a green felsite. They also resembled, though not very closely, the epidotic base of the Punugodu bed. I have seen no limestone elsewhere which resembles the Punugodu bed, but calderite was found in connection with crystalline lime-

stone in the case of a small bed of that rock at Kalpatti, in Trichinopoly district [1].

Graphite.

A graphitic gneiss was noted in one place within our gneissic area. This place is situated at the northern end of the rocky ridge south-east of Amravati (Umarawutty), close to the village of Peddamadur and a mile south of the Kistna river. The gneiss which contains the graphite in form of spangles is a decomposed quartzose rock.

Bezwada group.

The last variety of gneissic rock which demands our special attention is one occurring only in the extreme north-eastern corner of our gneissic area; but it there occurs in considerable beds, and forms the main mass of the group of hills on the right bank of the Kistna, opposite Bezwada. This variety of gneiss is a rather fine-grained quartzo-micaceous felspathic schist, containing several accessory minerals, chief of which are garnets of small size, but occurring in great numbers, and a reddish-brown felspar, forming small quasi-nodular aggregations, is also of common occurrence in the schist. The schist weathers considerably at the surface and becomes there of a rather powdery texture, or else coats itself with a close highly polished surface very like serpentine in appearance. This serpentinous mineral often shows various colours, and is then of considerable beauty. It is well seen on top of the westernmost ridge, south of the famous old Buddhist vihara at Undavilli,[2] also on the Mangalagiri hill.

The beds forming the Sitanagram and Undavilli ridges are continued across the river and form the Bezwada hills, in which they are also

[1] Mem. Geol. Survey of India, Vol. IV, p. 275.

[2] This very interesting relic of the Buddhist period is cut into this singular schistose rock at the north-western side of the extremity of the high ridge, close to the edge of the alluvium, and about half a mile from the right bank of the Kistna. The excavation was made without any reference to the strike of the rock, which it cuts diagonally; owing to this the weather action on the detached pillars, &c., has been much greater than had they been cut square to the planes of bedding.

The basement story of the vihara has lately been exposed by the very successful excavations proposed to, and carried out for, Government by Mr. Robert Sewell, M. C. S. An extensive rubbish heap had previously hidden great part of the front of the vihara.

characteristically displayed. They are so very distinct petrologically from any other members of the gneissic series known to the geological surveyors in Southern India, that they should be recognised as a well-marked sub-group, to which Mr. King, Deputy Superintendent, Geological Survey of India, and I, have given the name of Bezwada Series, after the small but important town of that name where the Kistna is dammed back by the anicut, or weir, which forces the water to flow into the series of great irrigation canals traversing the Delta. The anicut is built of the stone quarried at the south and north ends of the Bezwada and Sitanagaram ridges respectively, between which the anicut is situated.

At a cursory glance much of the stone used might be mistaken for a coarse and much weathered quartzo-felspathic grit, but closer inspection shows its truly metamorphic character, and moderately weathered masses show the micaceous ingredient of the schist quite distinctly. In the southern half of Sitanagaram ridge the beds show a dip of 65° close to the bank of the canal leading to Kommamur. In the Undavalli ridge the beds appear to have a rather higher dip, which increases to as much as from 70° to 80° in the eastern spur of the Mangalagiri hill, in which the beds make an acute curve, from north by 5°-6° east, to east-by-north. The eastern limb of this great curve disappears after a course of about 1½ miles under the alluvium of the delta. The greatest elevation of the Bezwada beds south of the Kistna is attained in the Mangalagiri hill, the trigonometrical station on the summit having an elevation of 889 feet above sea level. As seen from this point the several ridges and hills forming the highest points of the Bezwada series show a very remarkably level outline, as if the flat tops, speaking approximately, were remains of a former great plain of marine denudation. That such a plain did once exist appears quite certain from Mr. King's examination of the country north of the Kistna, where he found this feature largely developed. The remarkably level character of the ridge tops, and their near approximation in

Mangalagiri curve.

Plain of marine denudation.

height, are very noticeable from the summits of the granite gneiss hills, further west. Despite this uniformity of shape, the combination of hills with the large spreads of water in the Kistna renders the neighbourhood of Bezwada decidedly picturesque; especially so are the views from the top of Mangalagiri and the Undavilli ridge.

The connection between the Bezwada series and the adjoining granite gniess to the west and south-west has not been made out, no section having been found showing them in contact, or even in moderate proximity. As seen on the right bank of the Kistna, they appear to overlie the granite gneiss, and they certainly present a newer facies, as if they had undergone a lesser degree of metamorphism.

Considerable beds of quartzite are associated with the Bezwada beds in the main ridge north of the Kistna, but not a trace of them was noted on the south of the river, and I think the quartzite must have passed into the micaceo-felspathic schist, as it so often passes, in the south of our metamorphic area, into true mica schist.

The western schistose gneisses.

We must now return to the western band of the schistose gneisses, which includes the northern extensions of the several micaceous, hornblendic, and quartzose bands described above as forming the various ridges and valleys lying between Pámur and the eastern base of the Vellakondas.

West of the Podile hills.

The band of granitoid gneiss to which I gave the name of the Chendra Sekharapuram band, disappears to the northward of the village of Immedesheruvu, under the alluvium of the Pal-eru and the thick spread of red sandy soil, stretching away to the north-east. The rocks which then come into sight north of the red soil plain all belong to the schistose group, which then occupies the whole area between the lofty granite gneiss masses of the Kanigiri (Kunnigherry) and Podile (Poudellah) hills, and the northern extension of the Vellakondas. Mica schist is the predominant form of schist in this region, and next to it quartzite, which forms many long and important hill ridges. Hornblendic schists are

but rarely seen here, though so common in the eastern schistose band. The mica schist gives rise to only three hill groups of any importance; they are, the group of hills south of Mogalur (Mogulloor), the Kodnikonda south-west of Narrava Gopalpur, and the great hill north-east of Nandana Marrila (Nundana Morrala). Except where hilly, very little rock is seen in this quarter, the greater part of the country being covered with red sandy soil of great thickness. It is only in well-sections that the softer schistose beds are, as a rule, seen exposed, for the nullahs do not cut deeply enough into the surface to expose the underlying rock.

As already stated above (page 13), no connection could be traced with any certainty between the schistose rocks of the western band northward of Gogulapalle and those southward of that place; there would, therefore, be no use in making mere speculations as to any possible equivalency of several similar beds, even of the most remarkable of the quartzites. Very little can therefore be said of theses chistose rocks, for they present no special features of interest, either geologically or economically.

The several quartzite beds may be traced often for many miles, showing little change in mineral condition; but they then disappear, the ridges dying down gently under the surface soil, owing to the thinning out of the hard bands, or the graduation of the whole bed from hard quartzite into a soft micaceous rock.

It will be seen by the map that an important band of quartzite extends from the valley of the Pal-eru up to and beyond the Musi (Mooshee) river; they are then lost sight of; but about 4 miles to the north-east another very remarkable set of quartzites forms the mass of the great Chendalur hill. They in their turn are followed a couple of miles further north by other quartzites in the Ubiahpalliam hills. These two last groups of quartzites are remarkable for being the most northerly development of this variety of rock in this region, and for the peculiar positions they occupy with reference to the other adjacent members of the gneissic system.

Chendalur hill quartzites.

The quartzite beds of Chendalur hill are so strikingly like those of the newer Kadapa rocks, that, but for the existence of the great band of unquestionably gneissic quartzites above referred to, I should have unhesitatingly mapped Chendalur hill as an outlier of Kadapa rocks. As it is, I look upon the Chendalur quartzites as belonging to the gneiss, but with a lingering feeling of doubt, due, perhaps, to my having, when I first visited Chendalur hill, been strongly prepossessed in favour of its Kadapa age from its appearance as seen from the west and south-west. The quartzites are well exposed in a grand cliff at the south-western end of the ridge,[1] and the cliff recalls, though on a smaller scale, many of the grand precipices, scarping the Nagari mountains and the southern parts of the Vellakonda range.

The Chendalur quartzites are seen to rest, at the northern end of the ridge, on granite gneiss, to which they appear conformable; to the west they appear to dip conformably under a bed of iron-grey quartzose gneiss; while at the south-western end of the ridge the quartzites dip, also in apparent conformity, under the hornblendic beds close to the village of Bundevaleganla. Viewed as a whole, the Chendalur hill appears to be the southern extremity of a narrow and much contorted anticlinal ellipse. The beds have a quaquaversal outward dip on all sides but the north. I failed in tracing any signs of faulting, which must exist supposing the anticlinal ellipse to be an outlier of the Kadapa rocks.

Intercalated between the quartzites on the back of the anticlinal is a thick bed of slaty argillaceous schist, which being much softer than the quartzites has been deeply eroded, and has thus given rise to the formation of a small but deep valley in part of the hill mass.

[1] As seen from a distance from the west and east, the outlier of the southern end of Chendalur ridge presents a most striking likeness to a gigantic hippopotamus standing half immersed in water and looking south. This resemblance to an animal does not appear to have struck the natives, owing doubtless to their non-acquaintance with the genus hippopotamus.

Ubiahpolliam hill quartzites.

The quartzite beds in the Ubiahpolliam hill form likewise an anticlinal ellipse; they are overlaid conformably by hornblendic schists. No connection could be traced between these and the Chendalur quartzites; and, unless the respective positions of the two sets has been affected by faults hidden by the intervening thick spread of red soil, the Ubiahpolliam beds underlie the others at a considerable depth.

Change of character of rocks.

The predominantly micaceous character of the schists noted to the southward of the Musi-eru is not continued north of that river: numerous hornblendic beds now come in, and by the time the Gundlakamma valley is reached, to the south of Vinukondas, the two varieties seem to be equally common. Northward of the Gundlakamma river the schistose band widens greatly, and makes a trend to the north-east, thereby maintaining a general degree of parallelism with the boundary of the Kadapa rocks. To the north and east of Narsaraopett (Atlur Narasaraopetta) the continuation of the schistose band is greatly obscured by the extensive and unbroken spreads of cotton soil which cover the face of the country generally; and ere it reaches the banks of the Kistna to the west of Amravati, it has diminished to a strip of only a couple of miles in width.

Epidotic gneiss.

Two occurrences of gneiss containing epidote in the form of pistacite were noticed near Narasaropett; the one at Pamidipadu, 4 or 5 miles north of the town, the other at Ravipadu, 3 miles to the north-west. Epidote is but rarely found in this region, though by no means an uncommon mineral in more southerly parts, in South Arcot for example.

Magnetic bed.

Only one bed of magnetic iron was observed in the western schistose band; it occurs at Yerraguntlapadu, 4 miles south-east of Sattenapalle. Very little is seen of the bed, which crops out a little to the north-west of the village, and is by no means a rich one.

2.—The Granitoid Areas.

To the granitoid group belong all the highest elevations in the gneissic area, *e.g.*, the Kanigiri Drúg hills, the Podile and Chimakurti hills, the Bogala Konda, the Yenema Konda and Yerra Konda (near Kommalapadu), the Kotappa Konda, the Kondavidu hills, and lastly the Bellam Konda. A great number of smaller hills also consist of granitoid gneiss; but of these only four groups need be named, the Vinu Konda hills, the Darisi hills, the group around Rámákur to the north-east of Addanki, and the small hills around Nadella (Nadendla) to the south-west of the Kondavidu hills.

Varieties of granite gneiss.

Three several forms of ternary granitoid gneiss were observed, the hornblendic, the micaceous, and the epidotic, to state them in the order of their relative importance and frequency of occurrence. Very frequently, however, the rock appears to be binary in its composition, only quartz and felspar being visible, and the closest search failing to show the third ingredient, unless a freshly fractured surface extending far beyond the weathered surface of the rock is obtainable. This is especially the case in but slightly micaceous varieties. Owing to this difficulty the exact nature of the rock was not obtainable in a large number of cases in which no quarries existed to afford really fresh sections, it being quite beyond the power of an ordinary geological hammer to break up the great rounded weathered masses sufficiently.

In some few instances the granitoid rock contains both hornblende and mica, but then one or other of the two is to be looked upon as a mere accessory mineral.

Areas of predominance of hornblendic rocks.

Though in very many cases beds of the two principal ternary varieties, the hornblendic and the micaceous, are met with together in alternate strata, one or the other generally predominates over a certain area; such areas for the hornblendic variety are the environs of Pedda Allavalapad and Cherlupally, the

country east of Kanigiri, the Chimakurti mountain, the great spread of hornblendic, mostly trappoid, gneiss around Pothakamur (Poothkamoor), a very similar trappoid spread forming the Bogalakonda and adjoining hills, the Kotappakonda and the Ramakur hills. Another area of intensely hornblendic beds is found to the north of Guntúr, in the Lam, Tadikonda, and Nirukonda hills. The micaceous variety occurs principally in the Kanigiri and Podile hills, also in the group of low hills on the border of the Darisi and Vinukonda taluqs, and in the Vinukonda hills. In the Kondavidu hills and in those lying between Guntur and Amravati the two varieties occur together in about equal proportions.

Areas of predominance of micaceous rocks.

The epidotic variety forms the mass of the Bellamkonda in Sattenapalle taluq, and occurs also in the lower hills extending northward towards the Kistna. Epidotic gneiss occurs also in the inlier north of Vinukonda, at a place half-way between Sarikondapalem and Vaddagunta.

Epidotic granite gneiss.

The most characteristic display of the granite gneiss in its scenic features takes place in the Kanigiri and Podile hills, and in the granitoid area around the Bellamkonda, in the extreme north of our area. In these localities are numerous examples of "blocky" structure, whole hills appearing built up of loose masses with slightly rounded angles. Perhaps the finest example of this is furnished by the Kanigiri Drúg hill.

Scenery.

The granitoid characters are rather less pronounced in the Kondavidu hills, the bedding having on the whole been less obliterated than in the granitoid tracts last mentioned. They form the most picturesque group of hills throughout the Guntúr-Ongole region, especially as seen from the north-west or southwest. They must, however, yield the palm to the Kondapilly hills, immediately north of the Kistna, which appear to be formed of an extension of the same series of beds. The Kondavidu hills consist of two principal ridges, which do not correspond with the great lines of bedding, but

The Kondavidu hills.

seem due to a system of jointing[1]; near the middle of the western ridge, which is rather the lower, stands the well known old *drúg*, or hill fort, now an extensive but most picturesque ruin well worthy of a long visit by every lover of grand rock scenery.

The western slopes of both ridges are much more precipitous than the eastern ones. The highest summit, called Sheikh Adam ka Pahar, after a Mussulman saint whose tomb stands close to the summit, attains the height of 1,680 feet above sea-level.[2] In some of the hollows near the summit there remain a few patches of thick jungle, showing that the present barrenness of the hills is due to human agency, and not to any barrenness of the soil.

Bellam Konda Drúg.

It is noteworthy that the three principal hill fastnesses in this quarter have been built on the granitoid hills; they are Kondavidu, just described, Bellam Konda, and Kanigiri. Of the three, Bellam Konda Drúg was much the strongest by position, as it occupies the whole summit of the mountain, whose flanks are very precipitous. Like Kondavidu it is very picturesque, and commands a most interesting view over the singularly faulted and broken eastern boundary of the Kadapa rocks. If the great northern peak of the Bellamkonda could be made accessible so as to get an unbroken view of the Kadapa boundary up to the Kistna, it would afford to the stratigraphical geologist a panorama worthy of a long pilgrimage.

Kanigiri Drúg is formed by the fortification of the crests of two high ridges enclosing a narrow valley running north-east in its northern, and south-east in its southern half. Very little remains of the old buildings except a couple of gates at the northern and south-western ends, but in olden times it was a place of great note, and the object of a good deal

[1] The time at my disposal was unfortunately so much curtailed by a serious illness, that I was obliged to forego the pleasure of climbing to the highest points on the hills, from which alone the real relation of the bedding and jointing on a large scale could be made out.

[2] This is the height according to the measurement made by the officers of the Revenue Survey Department. The old Trigonometrical Survey measurement gave 1,749 feet.

of fighting. The upper part of the central valley lies in the strike of the bedding. The extent to which the southern peak[1] has been cut up by jointing is quite extraordinary, and the natives say the peak is inaccessible from its extreme ruggedness. This statement is probably based more on their fears of some leopards which inhabit the caves on the hill, than upon the real inaccessibility.

Chimakurti mountain.

The most important and conspicuous mass of the hornblendic variety is the Chimakurti mountain. As already mentioned, the hornblendic rock here forms a great elliptical area, 8 miles in length and nearly 5 across its greatest width. The southern half of this ellipse is occupied by the mountain and its rocky spurs, which extend some distance into the northern half. At the extreme north end are two considerable and very rugged hills formed of the same intensely black rock. The whole mountain is very bare, and but little soil exists for vegetation to be possible, and the usual native recklessness has denuded the slopes of what little wood might grow there if any attempt at conservation were made. Despite the bareness of the mountain, the bedding of the rocks is not easy to make out, it being very obscure to begin with, and also much concealed by the great masses of loose and confusedly tumbled blocks which cover much of the summits and slopes. It is best seen by descending some distance on the northern side of the summit, to where a good view is obtained of the great northern spurs. The southern elliptical curve is distinctly traceable here, though very obscure on the southern slopes. The rock is a coarse hornblendo-felspathic, and apparently quartzless, compound of dark greyish-black colour weathering to absolute black. The north-east faces of the various summits are all coated with grey and white lichens, due doubtless to the effect of the north-east monsoon. The highest summit, on which is a Trigonometrical Station, attains the height of

[1] I was unfortunately unable to get a guide to show the way to the summit, which must command a noble panorama, and had not the time to seek a path for myself through the bewildering chaos of large blocks amongst which no track can be made out from below. I think the summit would certainly be reachable from the north side.

2,097 feet above sea-level, and commands a very extensive and fine view over both sea and land.[1]

The bedding of the rock in the northern hills is obscure in the extreme, but there can be no doubt as to the position of the underlying band of quartzites so well displayed in the low ridge south of Rámáchândrapuram.

The decomposition of this intensely hornblendic rock gives rise to the formation of much gravelly kankar (concretionary tufa), a great thickness of which is to be seen near the bund of the upper of the two large tanks standing within the northern apex of the synclinal basin.

The Chimakurti mountain is a great solid-looking mass, and possesses but few elements of the picturesque as seen from a distance. It looks best from the south near Chillamkur. From the north or north-east the concentric arrangement of the dark central mass of hornblendic rock and the surrounding quartzite beds is very distinctly seen. The soil covering the small area of approximately level ground close to the summit is of dark, nearly black, colour, a true humus in fact, and its existence proves that the mountain was formerly very much better wooded than now.

Tors.

Tors, or isolated blocks formed by the action of atmospheric agencies on rocks having a large spheroidal structure, or much cut up by systems of jointing, are common enough throughout the granitoid areas above referred to, but none of very remarkable size or boldness of outline were noted, and in these respects they are greatly inferior to the tors of other granitoid regions, *e.g.*, the neighbourhood of Adoni, in Bellary district, or the granitoid

[1] If the Government scheme of creating a new Collectorate, with Ongole as its chief town, be carried out, the Chimakurti mountain will probably before long be built upon and used as a sanitarium. Though not of great height, dwellers on the summit, where there is plenty of room for several houses at an elevation of 2,000 feet, would probably be out of reach of the terribly hot land wind. The absence of all jungle and the complete isolation of the mountain will also most likely prevent the formation of all malaria. The only real difficulty at first will be about the water-supply.

country around and south of Gingi fort, in South Arcot, &c. Only one group of tors in the Nellore-Kistna country has impressed itself on my memory, and that through its grotesque shape. This group, which when seen from the south by morning light has a most striking resemblance to a huge elephant charging a gigantic tortoise from behind, lies a few score yards off the path leading from Nakri Kallu, on the great trunk road, to Gundlapalle, 4 miles to the north-west, and about half-way between the two places. It belongs to the western granitoid band.

Porphyritic rock at Yikuru.

Of the small outliers of granitoid gneiss which, as before mentioned, occur here and there within the limits of the schistose gneiss bands, only one needs special mention; it forms a low rocky hill close to Yikuru, 3 miles west-south-west of Narasaraopeth. The rock here is a very typical porphyritic variety of rich purplish-grey colour, which might be quarried and converted into a very handsome building stone. The enclosed crystals are prisms of grey felspar imbedded in a hornblendo-felspathic matrix of darker colour.

"Trappoidth" granite gneiss.

The dark black variety of hornblendic granite gneiss which I have described as trappoid, occurs mostly in the central part of our area, and chiefly in two patches north of the Chimakurti mountain, the larger lying to the east of Pothakamur, in Darisi taluq, the smaller some miles to the north, on the left bank of the Gundlakamma, and running up to and including the Bogala Konda, the reputed centre of the numerous slight earthquake shocks that are experienced in the Ongole country.

The typical trappoid rock shows nothing but hornblende and felspar, in a crystalline mass of varying degrees of coarseness. Quartz is very rarely seen in it. The colour ranges from dark blackish-grey to almost absolute black. Weathered surfaces are often absolutely black, and the rock, when seen in detached masses not large enough to show the bedding, is not distinguishable from bedded hornblendic trap.

At Pothakamur.

This is markedly the case at the eastern end of the Pothakamur trappoid area above named, especially in the masses of rock seen about a mile to the north of

Thalur. Further west, on the higher ground between Pòthakamur and Mullamur, where huge surfaces of rock are exposed, the bedding becomes apparent, and a few rather less granitoid beds are interstratified with the ultra-crystalline beds. No section was met with showing this trappoid rock in actual contact with other varieties of granitoid gneiss, or with the schistose rock; but nothing was seen suggestive of want of conformability with the closely adjoining beds. The true character of

The Bogala Konda.

the "trappoidth" rock is best seen in the Bogala Konda, or "Charcoal hill," so called from its intensely black colour. This intense blackness, added to its nearly conical shape, and its supposed association with the slight earthquakes so frequent in the region around Ongole, has given rise to the idea that it is a volcanic cone. The hill itself presents, however, no signs of volcanic action. The summit is divided by an irregular saddle into three unequal divisions, the western being between 100 and 200 feet the higher. The summit consists of a huge chaotic accumulation of blocks roughly rounded at the edges by weathering, from among which spring a few stunted trees of the fig tribe. The bedding of the great band of hornblendic rock out of which the Bogala Konda rises can be very distinctly seen from the top, and traced by the eye for several miles southward. Petrologically these beds are identical in appearance with the Pothakamur beds, and they are very probably an extension of the same, though the actual connection was not traced.

On the eastern side of the Bogala Konda are considerable "screes," to use a term familiar in the English lake district; the fallen blocks appear to form as it were streams down the sides of the hill. Many of the blocks are so loosely perched that a very small impulse, such as the slightest shock of an earthquake, would suffice to overthrow them; and to the frequency of earthquakes in this region may safely be ascribed the extreme confusion of the blocks on the summit, between the present position of the vast majority of which and the direction of the great joint planes to which they primarily owed their existence, no connection can now be traced. This cause has probably also affected the

loose blocks on the summits of the Chimakurti mountain in a nearly equal degree, the majority of the blocks being of very moderate size. The great confusion existing among the fallen blocks on the flanks of the south peak of the Kanigiri hills already referred to (page 34) is doubtless also in a measure due to this earthquake action; but from the vastly greater average size of the blocks, they would only be affected by violent shocks, which are of much rarer occurrence.

The dip of the bedding of the Bogala Konda "trappoid" beds appears to be easterly, but is very obscure. A bed of ordinary hornblendic granite gneiss close to the western base of the hill has however a very distinct south-easterly dip.[1]

I only experienced one earthquake shock while working in the Guntúr-Ongole country, and that certainly did not emanate from the Bogala Konda centre. It was on the morning of the 11th March 1867, about 7 miles west of Vinukonda and 17 miles west of the Bogala Konda. The shock caused a distinct tremor of the ground, travelling from north-east to south-west, and was accompanied by a loud rumbling noise, lasting several seconds. Frequent slight shocks have been noticed by the officials and other residents at Ongole.

Beds of equally trappoid hornblendic gneiss occur at a few other places as inliers within the schistose area, *e.g.*, between Maddalur and Yanekepad, 12 miles west of Ongole; and again 8 or 10 miles further south-west, near Zarlapalem, on the path from Peddakandla Gunta to Tangella, and near the latter place. These latter beds are intercalated with beds of quartzose gneiss rolling in small anticlinals and synclinals. Similar trappoid beds, strongly simulating contemporary trapflows in their appearance, occur also north and west of Tangella and east of Byanapalem. Two other examples of intensely trappoid hornblendic rocks are worth mentioning. Both occur in the valley of the Man-eru, the larger and more important forming the Enemerla hill, 3 miles east of Pámur, the smaller forming a

Enemerla hill.

[1] Bogala Konda is probably between 1,200 and 1,300 feet high, and extremely steep on all sides. I went up the south-west side and found it a very stiff climb, especially over the scree near the summit. The panorama from the top was very disappointing.

low rocky hill 6½ miles further to the east-by-north. Enemerla hill is formed of bare black rocks rising to a height of from 300 to 400 feet above the surrounding plain. The quartzo-hornblendic rock is coarsely crystalline in texture, and towards the western end of the mass rather porphyritic; no bedding is seen, and its relations to the surrounding schistose gneiss is not clear, no contact of the two rocks being exposed. The Enemerla rock is not more trappoid than beds of crystalline hornblende rock unquestionably forming part of the gneissic series, and but for its position miles away from similar extra-metamorphosed rocks, I should not have any hesitation in regarding it as such a rock; but, as it is, I feel doubtful whether it may not be intrusive and trappean.[1] The same remark applies to the smaller trappoid mass south-west of

Ianakotay hill.

Ianakotay (Ianacota), but in lesser degree, as it is unquestionably associated with a set of highly hornblendic gneiss beds underlying the rather remarkable Ayawarpalle-Ianakotay quartzite band. The hill consists of great masses of rock, much weathered, rounded, but not sufficiently isolated and detached to be called tors. The hill is almost bare of vegetation, and of inky blackness.

It is not possible to examine the geological map of the Guntúr-Ongole

Parallelism of folding of gneiss and Kadapa rocks in this region.

region without being struck by the remarkable parallelism subsisting between the great foldings of the gneissic rocks and those of the Kadapa rocks in the Vellakondas and Nallamallas. The natural inference from this is that the gneissic series was affected by at least two great periods of (roughly speaking) east to west compression, and the Kadapa series by one such period, which was the second of the two. That the gneissic series had been compressed into huge folds at a period long anterior to the commencement of the Kadapa, is abundantly clear from the fact that such folds had undergone great denudation before the beginning of the deposition of the newer series. On the completion of the

[1] My examination of Enemerla hill in 1866 was not as full as I could have wished, owing to a very heavy burst of the monsoon, which came up and drove me away. No subsequent opportunity occurred of my revisiting the locality.

Kadapa series came the second period of great east-to-west pressure, which crumpled the eastern half of the Kadapa basin into huge synclinals and anticlinals, several of which are locally inverted. These upheaved and contorted strata were in their turn exposed to denuding agencies, and underwent considerable waste before the series of rocks, called by Mr. King[1] the Karnul series, began to be deposited. The completion of this series was followed by another period of disturbance and upheaval, during which most probably a great fracture of the earth's crust took place a little to the east of the line of greatest contortion of the Kadapa rocks. This fracture formed the set of faults now seen to exist along the greater parts of the eastern boundary of the Kadapa basin, and coinciding nearly everywhere with the eastern foot of the Vellakonda range.

This fracture was accompanied by great displacement of the rocks on either side, and those on the eastern side were greatly upheaved. Subsequently to this, denuding agencies attacked the upraised area with intense energy and removed the superincumbent Kadapa rocks almost entirely, leaving in our area only a few outliers, namely, the Bairawudi Konda quartzites and slates, and the same set of beds in the unconformable patch east of the great fault at foot of the Gali Konda (Gauly Conda) in the south, and the Biravallipaya and Atchammapett "faulted domes"[2] in the north-east. To the south of our area are the very striking outliers forming the Udayagiri Drúg and the Korise Konda. The Yerra Konda and Durgamma Konda, still further to the south, are doubtfully of Kadapa age. None of these gives any clue as to the limit of the former eastward extension of the Kadapa basin over the crystalline rocks.

[1] The names of Kadapa and Karnul series were given by Mr. King of the Geological Survey of India to the two great series of submetamorphic rocks occurring in the Madras Presidency.

[2] The northern end of the eastern boundary of the Kadapa basin is characterised by a singular series of elliptical anticlinal domes, six in number, extending from Vinukonda nearly up to the Kistna. The two northern ones are true outliers faulted into the gneiss on all sides.

The members of the gneissic series are generally too coarse in texture to show true slaty cleavage well; moreover, it generally coincides with the edges of the planes of deposition, and is therefore easily overlooked. For these reasons but very few instances of it were noted, the chief of these being among the mica schists 7 miles to the north of Pámur, and the slaty schists on the back of the Chendalur anticlinal (see page 29); but neither of these are of any special interest. A case of some interest, of cleavage in a quartzite bed, was observed in the western arm of the synclinal curve formed by the beds which make up the Picherla Konda (see page 14). In this case one of the lowest of these beds (a little to the south of the village of Balla Venkatapur), which has an east-to-west strike with northerly dip, is at the point where it curves eastward an ordinary quartzite, showing no special features; but as it extends westward it becomes cut up by vertical cleavage planes[1], which become more and more numerous westward, and are lined with a film of greyish mica; the quantity of mica increasing with the number of cleavage planes, till, just as the spur sinks down under the local alluvium of the adjoining nulla, the rock is almost an absolute mica schist. The intermediate gradations were instructive, showing the progressive changes dependent on a very peculiar form of metamorphism. The half-way gradation had a strong general resemblance to a coarse "blotchy" porphyritic gneiss, which no one who had not seen the gradual change would be inclined to regard as the possible outcome of extra-metamorphic action on a true quartzite.

Slaty cleavage in gneiss rocks.

Singular result of cleavage in quartzite.

A great show of cleavage of clayey mica schists may be seen in the Nandana Marrila hills north of Kanigiri. In this case the cleavage coincides actually, or very nearly, with the lamination of the true bedding.

[1] They might be mistaken for jointing where they first begin to show, but a little further west they become far too numerous to be regarded as anything but cleavage planes.

3.—Intrusive rocks in the Gneissic area.

All the intrusive rocks occurring within the gneissic area being, as far as at present known, of greater age than the overlying Kadapa rocks which they are nowhere seen to penetrate, it will be convenient to consider them before proceeding further. The intrusive rocks seen are referable to the following four groups: (*a*) Trap dykes and intrusions; (*b*) Granite veins; (*c*) Felsite veins; (*d*) Quartz veins.

a.—Trap dykes and intrusions.

Rarity of trappean rocks.

As compared with many other parts of the great gneissic region of Southern India, the Guntúr-Ongole area is remarkable for the extremely small number of trappean intrusions that have taken place in it. Not only is the number of such intrusions small, but they are mostly of very small size, and in every way of extremely small importance geologically. One exception may perhaps be made, but in this case the really trappean character of the rock is very doubtful; it relates to the black hornblendic mass of the Enemerla hill east of Pámur, already described above (see page 38). From its isolated position this mass suggests the idea that it is intruded among the highly schistose beds which surround it; but unfortunately the contact between the two could not be traced. The petrological characters of the mass are so extremely like some of the other highly hornblendic metamorphic beds, that they do not afford, without special chemical or microscopical analysis, sufficient evidence safely to decide their exact nature. The same remarks apply, though in lesser degree, to the equally doubtful hornblendic rocks of the Ianakotai hill occurring 6 miles to the east-by-north, near the village of Ayawarpalle.

Dykes.

All the other unquestionably trappean intrusions occur in the form of true dykes. The greatest number of these occur in the granitoid gneiss region around the Bellam Konda, in the Kistna valley. A few occur in the lower part of the Gundlakamma valley, and a small group in the upper valley of the

Musi river; the remaining few are scattered about here and there at very great distances from each other. The dykes are all dioritic in character, and many of them, especially in the northern group, distinctly porphyritic, showing numerous whitish felspar crystals. The diorite is mostly blueish or greenish black in colour. Exceptions to this rule are the dykes occurring at Ongole (on the Trigonometrical Station hill), and Neputlapadu, 3 miles east of the southern end of Chimakurti mountain. The former is of greenish-whitish grey colour, the latter of a purplish-blackish grey.

Referred to two systems.

The majority of the dykes may be referred to two systems, depending upon the direction of their strike, one of these systems having a course from north-15°-west to south-15°-east, the other running north-east-by-east to south-west-by-west.

All these dykes were intruded prior to the deposition of the Kadapa rocks.

b.—Granite veins.

Granite veins, except of very small size, are not at all common in the gneissic area, and none were met with of any importance either from size or special geological interest.

Some small veins of quartzo-micaceous granite traversing the schistose gneissics to the south-west of Kambaldinna, in the central part of the valley of the Man-eru (river), contain small garnets and prisms of tourmaline. Tourmaline occurs also in granite veins south-east of Petlur (18 miles south-west-by-west of Ongole). The tourmaline occurs here in some quantity, and good prisms are obtainable. Hemihedral crystals are not common, and the colour of the tourmaline is always black. A granite vein containing unusually large crystals of orthoclase felspar was observed in the bottom of the great tank west of Kondapy, at its upper end. Well shaped prisms of very pale flesh colour, 4 to 6 or 8 inches long and proportionately thick, were noticed, but were mostly too much cleaved to be extricable without breaking up into small fragments.

Small irregular granite veins of pale pink colour and coarsely crystalline texture are common in the micaceous and hornblendic schists south-east of the Chimakurti mountains, but they offer no points of special interest.

c.—Felsite veins.

A small series of hard vein-like bands of light coloured rock, having considerable resemblance externally to quartzite, traverse the hornblendic gneiss south-west of Pothakamur (Poothkamoor of sheet 76).

These veins—for such they undoubtedly are—as they cut across the beds of gneiss at an angle of 45°, consist of compact felsite of pale bluish-grey colour, weathering a very pale cream colour. The freshly broken surfaces of unweathered parts of the rock show here and there sections of flesh-coloured crystals of felspar. The veins are small, being only 3 to 4 feet thick, and exposed only in short lengths. They occur over a tract about 2 miles long by a mile in width, which they traverse in a north-east to south-west direction. Though tolerably numerous, the veins form an inconspicuous feature in the landscape, and might be easily passed by unnoticed.

No other occurrence of felsite rocks was observed in the Guntúr-Ongole region.

d.—Quartz veins.

Quartz veins are numerous only in parts of the gneissic area, but, like the granite veins and trap dykes of this region, they are, with but few exceptions, of very small importance and size. The most remarkable exception is a considerable mass of quartz on the south side of the faulted southern boundary of the anticlinal ellipse west of Nakarikallu, at a spot close to the intersection of the meridian of 80° east longitude by a parallel drawn in latitude 16° 20′ north. Though covering a large surface, the relations of the quartz to the fault are obscured by debris and soil, and it does not show any characteristics of being a fault rock, as might very well be inferred from its position.

At Nakarikallu.

South of Vinukonda.

The other quartz veins to be noticed occur mostly a little south of Vinukonda, near the villages of Ayanavolu, Payidipadu, and Ravaran. At the two latter villages the quartz veins run due north and south. They are traceable only for short distances. In the extreme south of the gneissic area numerous large north and south veins occur in the schistose gneiss of Dukanur hill, about 4 miles east-south-east of Pámur. Minute veins, such as characterize many mica schists and kindred rocks, occur in immense number, especially in the southerly parts of the gneissic area, and often give rise to prodigious accumulations of debris, by which the whole surface of considerable tracts of country is almost perfectly masked. Such is notably the case in the tract between Pámur and the Paleru valley.

No quartz veins were seen containing sulphides of iron, &c., or any other indications of the presence of gold.

Some small veins of milky-white quartz traversing the garnetiferous hornblendic and micaceous schists east of Bianapalle (on the banks and in the bed of the little Makeru river, which rises among the southern spurs of the Podile mountain) are wonderfully charged with minute dodecahedrons of brownish-red garnet.

CHAPTER III.—THE KADAPA SERIES.

Assuming the numerous quartzite beds occurring within the gneissic area to be really members of that older metamorphic series, the newer or Kadapa series is but very slightly represented within our present limits, and only in the shape of a few patches, mostly outliers, four of which only require special notice, having already been partially dealt with in my notes [1] included in and appended to Mr. King's memoir on the Kadapa and Karnul series.

[1] Memoirs of the Geological Survey of India, Vol. VIII, pp. 218 & 293.

Bairawudi Konda outlier.

The first outlier to be noticed is that capping the Bairawudi Konda, in the extreme south-west corner of our gneiss area, where it forms a very conspicuous object, as it rises into a considerable mountain, surrounded in most places by a cliffy scarp. The outlier forms a small synclinal basin, out of the middle of which rises a great mass of coarse micaceous and chloritic schists, capped by a higher set of quartzites, forming the highest summit.

The lower quartzites rest with great unconformity on the upturned edges of a great series of mica schist beds. They are doubtless a northern extension of the great beds capping the Udayaghiri, a few miles to the south; but there has been an appreciable thinning out of the quartzites between the two mountains, and the cliffs of the northern mountain are much inferior in height and beauty to those which rendered Udayaghiri such a famous stronghold in former ages.

The relations of the Bairawudi Konda beds to those exposed in the main mass of the Vellakonda range have been illustrated in a section given in Mr. King's memoir (*l. c.*, page 222). The lower quartzites of the outlier correspond to the Cheyair group of the series into which Mr. King divided the Kadapa formation of that region.[1]

The lower quartzites occur in thick beds of whitish or buffy colour. At the northern end of the mountain they are much contorted, and the synclinal fold they form is beautifully shown in a fine vertical cliff more than 100 feet high, at the southern end of a deep and very picturesque ravine opening northward towards the village of Kothapalle. During the rainy season a small stream falls over this cliff[2], above which comes a considerable thickness of chloritic

[1] Memoirs of the Geological Survey of India, Vol. VIII, p. 126.

[2] Several small rock temples, probably of Buddhist origin, have been cut in the mica-schist on the slope of the spur on the western side of the ravine, and a few small niches on the face of the quartzite cliff; they are now sacred to Konabairuru deva, the deity of the waterfall.

quartzite, and above this are chloritic and micaceous schists of dark green colour and coarse texture, which form the central mass of the mountain rising out of the rudely elliptical synclinal basin, and surrounded by a broad lip, or margin of the lower quartzites, as shown in the section, fig. 2, page 14. The summit of the mountain is formed by a capping of younger quartzite. A small, but very conspicuous, outlier, consisting of the lower beds of the basement quartzites, caps the high hill rising about a mile south of the mountain.

Gali Konda patch.

A northern extension of the older quartzites occurs on the eastern side of the Tungur (Toongoodoor) pass, about 10 miles to the northward[1]. Here a remnant of the (local) basement quartzites has been left, abutting with its left or western side against the quartzites and slates here forming the mass of the Vella Kondas. There can be no doubt that, as already pointed out (page 11), the great line of fault, by which the Kadapa basin is abruptly bounded along the eastern flank of the Vella Kondas, passes along the axis of the valley lying between the lofty spur formed by the eastern edge of the patch of basement quartzites and the slope of the mountains locally distinguished as the Gali Konda (Gauly Conda).

The basement quartzite dips westward, while the quartzites of the main range dip eastward, and thus appear to form an ordinary synclinal; in reality, however, the quartzites of the western slope occupy a considerably higher position in the Kadapa series than does the basement quartzite, and the synclinal valley is, therefore, not an ordinary one, but one with unconformable sides.[2] The basement beds thus constitute an outlying patch *de jure*, to which I will give the name of the Gali Konda patch.

[1] By some oversight this outlier of basement quartzites has not been shown on the map accompanying Mr. King's memoir with the same colour as the Udayaghiri and Bairawudi Konda outliers, though unquestionably of the same age.

[2] I could not examine this valley nearly as closely as I could have wished, owing to the extremely rugged nature of the country at foot of the mountains, which compelled me to camp at a great distance from the gneissic boundary.

Biravallipaya outlier.

The next outlier of the Kadapas requiring mention in these pages occurs 85 miles to the north-east-by-north of the last-named one. It is one possessing considerable interest on account of its remarkable stratigraphical position, the peculiarity of which consists in the mass being an elliptical anticlinal dome let down among the gneissic beds by a series of faults, by which it has been cut into an elongated rather irregular hexagonal area, whose major axis extends about 7 miles north-east-by-north, the minor measuring about 5 miles from north-west-by-west to south-east-by-east.

The top of the dome has been much denuded, and the quartzites and other rocks cut away so much in the centre of the ellipse, that the underlying granitoid gneiss has been exposed in a narrow longitudinal valley, in which stands the hamlet of Biravallipaya. The dome is made up of four principal quartzite beds, which are separated from each other by three bands of slate. Here, as elsewhere, wherever the basement of the Kadapa rocks is seen, it is formed by a quartzite. As seen from the south-west, the slope of the hills is characterized by the bare surface of one of the quartzite beds dipping south-west at an angle of 30°; and which presents very much the appearance of a glacis leading up to the walls of a great fort. The dip of the beds on the south-east and east side of the dome is from 45° to 50°, showing the anticlinal to be an unsymmetrical curve. The highest remaining part of the dome, which lies near the northern end, attains the elevation of 1,379 feet over sea-level, and is crowned by a trigonometrical station. None of the beds exposed in this Biravallipaya dome could be identified with the beds forming the eastern part of the Nakarikallu elliptical anticlinal, though they are separated by so small a distance.

Atchammapetta outliers.

A similarly faulted dome forms the outlier west of Atchammapetta, and about 5 miles south-west-by-south of Chintapilly, on the Kistna river. In this case the out-lier has a rudely trapezoidal figure in plan, the greatest length of side being about 1½ miles. It forms a low broad-backed hill, of

which the greater part of the surface is bare quartzite, of brown and drab colours, with a quaquaversal dip. The apex of the dome lies considerably westward of the true centre. Though cut into by a deep ravine on the north side, the arch of the dome is not cut through, and the underlying gneiss is not seen. No point of actual contact with the gneissic rocks is seen, but to the north of the dome is a large dyke of dioritic trap of the gneissic series of dyke which is older than the Kadapa system. North of this dyke is another outlier, also a domoid anticlinal, but of much smaller size, being only about ⅓ mile long by ⅛ wide, but consisting of bluish-drab and grey quartzites, unlike any of the beds seen in the greater dome. These two faulted anticlinal outliers complete the list of outliers of Kadapa age south of the Kistna.

CHAPTER IV.—THE UPPER GONDWANA SERIES.

The formations belonging to this very interesting and important division of the mesozoic rocks occur in numerous patches, mostly of small size, lying, with a few exceptions, along the eastern boundary of the gneissic area and dipping under the younger lateritic and alluvial formations. The exceptions are a few inliers situated within the area of the younger formations. These, with the exception of two inliers on the western border of the Kistna delta near Guntúr, are of trifling importance. Counting large and small patches, they number twenty-four, of which two possibly may be considered rather doubtful, being referred to this series solely because of their position. These will be referred to again further on. Besides the patches which were of sufficient size to be mapped, there are many other small exposures of these Gondwána rocks in wells and water-courses, showing that they are really much more extensively developed than they appear to be on the map. If the alluvium could be removed, the Gondwána beds would show a surface several hundred square miles greater in extent than that which they now

exhibit. For convenience in describing the several patches, they may be taken in four groups:—

Distributed into four groups of patches.

1. The Kandukur (Cundacoor of sheet 76) group.
2. The Ongole group.
3. The Vemávaram-Budaváda group.
4. The Guntúr group.

Of these, the Vemávaram-Budaváda group is by far the most extensive, the most diversified in petrological features, and the richest in organic remains.

In the *Kandukur group* I include the various patches in the valleys of the Vupput-eru and Man-eru, and those occurring within or bordering the Kandukur laterite area; also a small outlying patch, a mile east of Ilavara (Yellavurra of sheet 76), 11 miles north-north-west of Kandukur.

The *Ongole group* consists of two patches and several small exposures of shales about 6 miles west of Ongole town.

The *Vemávaram-Budaváda group* includes all the patches lying between the Gundlakamma and the Perachur river. Of six patches, four are of importance; these are the Vemàvaram, Budavàda, Idupulapadu, and Pámur patches, called after the geologically most important villages situated on them.

The *Guntúr group* consists of three patches, two of which are of considerable size; the Tangellamudi and Chebrolu (Bebbralu of sheet 95) patches lie in the alluvium of the Kistna delta to the south-east of Guntúr. The third, of small extent, lies within a laterite area, 15 miles south-west of Guntúr. Besides these, there are a number of exposures through the lateritic deposits just alluded to, and also through that occurring at Guntúr itself.

The Kandukur group.

The most southerly of these four groups, the Kandukur group, is composed of a considerable number of small and widely scattered patches, all occurring, as already stated, in the valleys of the Man-eru and Vupput-eru, or bordering the

Kandukur laterite area, with exception of a small patch which lies 11 miles north-north-west of Kandukur, and a little east of the village of Ilavara (Yellavurra of sheet 76). The group consists of thirteen separate patches, all but three being very limited in extent. Of these three the most southerly lies on the 15th parallel of north latitude, close to the village of Chinna Latarapy, on the right bank of the Vupput-eru. It covers only about 3 square miles of surface, but is doubtless connected below the alluvium and lateritic beds with other smaller patches which occur at small distances to the north, east, and west. The well-sections south of Chinna Latarapy show brown micaceous sandstones, sometimes very thin-bedded and pebbly near their base, which rests on the gneiss. The beds have a south-easterly dip, and the plant remains they contain cannot be determined.

Chinna Latarapy patch.

Traces of gritty or conglomeratic sandstone beds, in the shape of patches too small to be mapped, are found dotted here and there over the gneiss inlier east of Chinna Latarapy, and show the contact between the two rock-series very distinctly. Many of the patches are only a few inches across. The sandstone is composed of gneissic debris, chiefly quartzose in character.

At the western extremity of the western bank at Chinna Latarapy, thin-bedded friable drab micaceous sandstones are exposed, which show a dip of 2° to 3° to the north-west-by-north.

South-west of Chinna Latarapy, at the village of Ramnaikenpett, drab sandstones with intercalated thin shaly beds are to be seen; in one well-section they are exposed to a depth of 16 feet, and show a dip of 7° to 8° to north-north-west or north-by-west. In the nullah feeding the Ramnaikenpett tank, the following succession of beds was noted :—

Ramnaikenpet section.

Sandstone, pinkish-brown.
Ditto, greyish-purple.
A break ————
Sandstone, very coarse, pale reddish-brown.
Ditto, coarse, micaceous, pink and purple.

Sandstone, whitish-grey.
Ditto, grey.
Ditto, shaly, yellow-brown.
Ditto, ditto, purple.
Ditto, purple.
Ditto, micaceous, pinkish-brown.
Grit, shaly, dark purple, ferruginous.
Gneiss.

These beds roll about a good deal, and are locally often obscure, besides showing false-bedding, but the general dip is westerly at a low angle. A large mass of silicified wood was observed in one of the beds at the top of the series, but no other fossils were found in this section.

Pedda Pamidi section.

A couple of miles south-west-by-west from Ramnaickenpett, at the village of Pedda Pamidi (Pedda Powenny), drab friable sandstones are exposed to a depth of 15-16 feet in well-sections, under several feet of kankar and lateritic gravel. Separated from these sections by about half a mile of alluvium, is a fair section exposed in the right bank of the Vupput-eru, at its junction with the Mutialpad nulla. The succession of beds is not very clear owing to the broken nature of the bank and to the want of definition of the several beds, which have a tendency to graduate one into the other. The beds, which have a general north-westerly dip, never exceeding 8° and generally much less, succeed each other in the following order:—

Sandstone,	shaly, Indian red and drab ...	... 1′
Ditto,	drab	... 1′
Ditto,	shaly, drab and Indian red ...	... 0′ 8″ to 0′ 10″
Ditto,	ditto in parts, mottled red and brown	... 2½′ to 3′
Ditto,	ditto, Indian red and drab ...	... 3′ to 4′

Peddavaram bluff.

Some 6 miles to eastward of this last section is a low rocky bluff, consisting of coarse gritty conglomerate and sandstones, rising out of a jungly plain and lapped round by laterite gravel. This bluff is formed by a small remaining patch of Rájmahál rocks resting on gneiss, which shows a very little distance to the south: the conglomerate and sandstones are of no great thickness,

probably not more than, if as much as, 50 feet. Resting on the surface of the sandstones are concretionary fragments of purple clayey sandstone, containing plant remains of Rájmahál age, now worn into pebbles, and belonging to the lateritic gravels. Further north, 3 or 4 miles east of Chinna Latarapy, similar washed-up purple plant sandstones form a considerable proportion of the lateritic gravel resting on the gneiss. From similar purple grit and hæmatitic sandstone pebbles in the laterite gravel, unquestionable Rájmahál plant remains were obtained to the south-east of Razpalem, 3 or 4 miles north of the Peddavaram bluff just described. Among the plant remains here found was part of a frond of *Ptilophyllum* (*Palæozamia*).

Mogallur sections.

To the northward of the Chinna Latarapy patch of Rájmahále are several sections of plant beds, chiefly sandstone, to be seen in the Mogallur nulla, and in the bed of the Man-eru east of Mogallur. In the latter case, the friable brown micaceous sandstone yielded parts of broad *Ptilophyllum* fronds. This plant bed is overlaid apparently by the various sandstone and shale beds seen in the principal section in the Mogallur nulla which present the following series in descending order, the beds having a general dip of from 7° to 10° to the south-south-east:—

Shale, sandy, ferruginous	0′	6″
Sandstone, brown, friable	1′	6″
Kankar parting	0′	4″ to 5″
Sandstone, brown, friable	2′	6″
Kankar parting	1′	to 3″
Sandstone, brown, with grey and red shaly laminæ, much false-bedded	3′	
Sandstone, brown	4′	
Ditto, shaly, grey and red	0′	8″ to 10″
Kankar parting	0′	8″
Sandstone	1′	
Ditto, shaly, grey and red	0′	4″ to 14″
Kankar parting	0′	2″ to 3″
Sandstone, brown, micaceous friable	6′	
TOTAL, about ...	20′	

Gudlur sections.

Three miles to the north-east of the river-side section, plant beds are again seen in well-sections at the south end of the village of Gudlur. The beds here consist of soft drab micaceous shaly sandstone, with numerous fragmentary plant remains in horizontal beds divided by kankar partings. Only one identifiable fossil was obtained here, a small fragment of a *Dictyozamites*. A well-section north of two small ruined pagodas shows similar sandstone, with shaly partings of chocolate colour containing obscure fragments of plants in great abundance. The beds dip north-by-east at from $1\frac{1}{2}°$ to $2°$. From 10 to 20 feet of the plant beds are visible above the water in the several wells in which they are exposed. The surface is obscured by a thick deposit of kankar and lateritic gravel. Gritty mottled sandstones

Virapalle sandstones.

are found under the laterite to the south-west of Virapalle (Veerapully); they are probably of Rájmahál age. This completes the enumeration of exposures of Rájmahál rocks south of the Man-eru. There is a great degree of resemblance in petrological and lithological characters between these beds and those seen in the Alicur and Pyanur areas of the Rájmáhal series west of Madras,[1] the predominant feature in both cases being the soft and unconsolidated condition of the greater part of the constituent deposits.

North of Man-eru. Kalamalla sectio

To the northward of this river the first inlier of plant beds is met with at Kalamalla (Calamulla), but it is a very small and unimportant one. The beds seen in the north bank and bed of the river consist of drab and greyish-brown sandstones of moderate hardness, occupying a nearly horizontal position. The dip, if there be any, is slightly southerly. No fossils were found, but the lithological resemblance to the more southern beds and the geographical position justifies the conclusion that the Kalamulla beds are equally of Rájmahál age.

Polenanepalem section.

Friable micaceous sandstones of reddish-brown and grey-drab colours form a miniature cliff 5′ 7″ high on the south bank of the large nulla at Polenanepalem, 7 miles

[1] See Memoirs of the Geological Survey of India, Vol. X.

north-west of Kalamulla. This also is a very small inlier of Rájmahál beds among lateritic sands.

Chautapalem patch.

We now come to the Chautapalem patch, the largest of the Kandukur group, but which despite its size offers but little of interest, as it contains not a single good or instructive section, only a few poor well-sections, and no good fossils were obtained from the soft, often shaly, drab or brown sandstones they expose.

Ponnalur patch.

The Ponnalur patch, which is only separated from the foregoing by about a mile of overlying lateritic sands, shows soft shales and shaly friable buffy-brown sandstones underlying the lateritic beds at its northern extremity, close to the village after which it is called. Soft drab sandy beds are exposed in a well-section about a mile to the south-west. Plant remains are scarce and very fragmentary, but enough were found to determine the age of the beds beyond doubt.

Kovur section.

Between 6 or 7 miles to the eastward lies the village of Kovur, which stands on a narrow strip of Rájmahál rocks lying between the northern boundary of the Kandukur laterite area, and the alluvium of the Paleru, and extending rather more than 4 miles from east to west. A few good well-sections, south of, and close to, Kovur village, give some insight into the nature of the plant beds here occurring. The rock exposed is drab micaceous sandstone, shaly in part, having a north-easterly dip. Some of the more shaly laminæ, as exposed in the waste heaps of material dug out in sinking the wells, show recognisable plant remains, though but small and fragmentary parts of the plants are preserved.

Fossiliferous shales.

Among the specimens collected were fragments of three species of *Ptilophyllum*, and with them impressions of minute bivalve shells which were remitted to Calcutta for determination. The eastern part of the patch is greatly obscured by a remarkable bed of massive kankar-like limestone of undetermined age, which is especially developed at Kunda-Kandukur (Conda Cundacoor).

Unfortunately no section could be found throwing any light on the relation of this kankar bed to either the under or overlying deposits.

The nature of the small shells collected, whether marine or fresh water, has yet to be determined by comparison; they were of too small a size and inconspicuous a character to be safely determined off-hand.

Shales at Kandukur.

Some minute shells of precisely similar character were found on a well heap in the field about three-fourths of a mile north-west of Kandukur, and a few yards off the path leading to Kovur. These were associated with fragmentary plant remains. The beds seen in various well-sections, or their debris exhibited in the waste-heaps, shows the prevalent character of the rock to be drab or brownish-buffy sandy shales, or shaly sandstones with reddish laminæ. These rocks, whatever their character, are largely composed of scales of mica, and mostly very friable.

Anantasagaram and Yedlurpad sections.

Westward of Kandukur the Rájmahál rocks are seen in well-sections, and a few very shallow surface sections at several places at and around the villages of Anantasagaram and Yedlurpad. Shaly micaceous sandstone from a well just east of the former village showed just distinguishable traces of *Ptilophyllum*. This sandstone contains but few plant remains, and those few are very fragmentary. A well-section at Yedlurpad shows about 20 feet in thickness of drab shaly sandstone containing numerous concretionary surfaces, white and porcellanoid in appearance, and striated like a fine slickenside. Some concretionary masses also had their whole exterior covered with this glistening surface. This quasi-porcellanoid surface is due to the presence of a film, as a rule of extreme thinness, of calcareo-argillaceous material. Though porcellanic in appearance, the bright surface is really soft and very easily scratched.

East of Kandukur.

Eastward of Kandukur, chocolate-coloured shales were observed in the ditch by the side of the new high road leading from Kandukur to the great north trunk road at Singarayakonda, at a distance of about 3 miles from the former

place; and in a well-section close to south of the road which leads from the trunk road to the sea at Voolapalem, a section of purple and white mottled gritty shales, some 12 feet thick, may be seen. No distinct traces of plants could be made out in either locality; but the shales have a very strong resemblance to other unmistakably Rájmahál beds, as, for example, those of which traces in the lateritic gravel, at and to the south of the village of Razpalem, were referred to above, page 53.

Ilavara patch.

The one member of the Kandukur group of patches of Rájmahál beds lying northward of the Paleru occurs a mile eastward of Ilavara (Yellavurra), 10 miles north-north-west of Kandukur. Here, in the bed of the large nullah flowing eastward into the Musi river, and in several small gullies opening into it from the south, are to be seen beds of micaceous sandstone overlaid by grits and shales with clayey bands, all dipping southward at angles varying from 5° to 10°, or else rolling about. Another similar series of sandstones and shales, apparently underlying the above-mentioned beds, occur on the northern bank of the nullah, and on the banks of a small tributary from the north. One bed of sandstone low down in the series, exposed in the gully immediately west of the little hamlet of Netivaripolem (not shown in the map), contains a few rather large but much weathered boulders of gneiss, reminding one of the boulders so common in some of the beds at the base of the plant-bearing series in Trichinopoly district. In the bed of the large nullah a little east of the boulder bed the sandstones are very coarse and gritty; they roll about a good deal, but the general dip is low south-south-westerly. The shaly beds in the more westerly gullies yielded a very few plant remains of the most fragmentary kind, but only after long-continued search. The most recognisable specimen seemed to be part of the mid-rib of a *Ptilophyllum* frond. This small patch of plant beds appears to owe its continuance to the fact that it is sunk in a depression in the gneiss, and has therefore escaped the full force of the erosive agencies which have so greatly affected the Rájmahál beds over a large part of this particular region.

The Ongole group of patches.

The second or *Ongole group* of patches of the plant-bearing beds consists of only two patches, the southernmost and smaller of which lies 11 miles north-east of Ilavara and 6 miles west-south-west of Ongole. This patch is greatly obscured by the overlying thick cotton soil; the only tolerable section found is seen in a small well on the east side of the road leading from Konijadu (Conjadoo) to Santanuthatapad. The western side of this well shows the section illustrated

Section south of Mangamur.

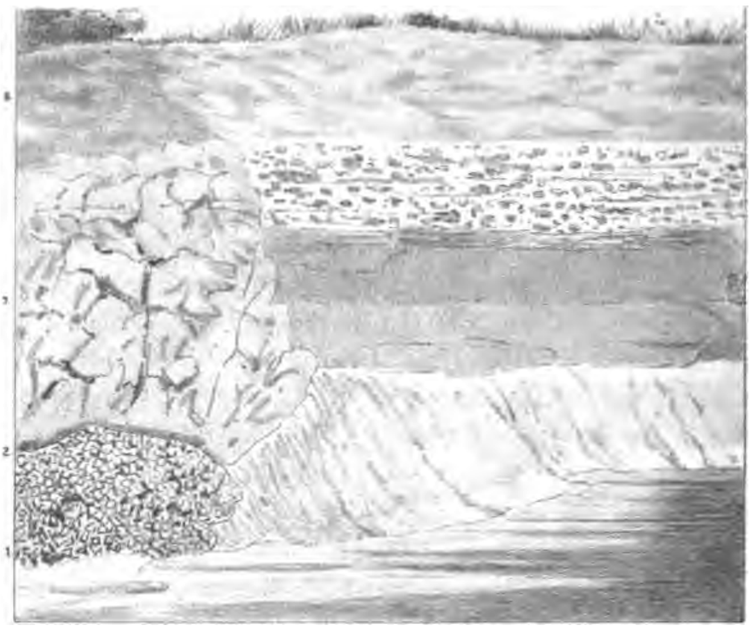

Fig. 3. Well-section south of Mangamur.

in the accompanying diagrammatic sketch. The base of the Rájmahál rocks is here formed by a gritty red sandstone (4), resting on coarse, highly felspathic granite (1). This sandstone is seen to pass suddenly into a singular rock (3), partly conglomerate, partly breccia, with a calcareous matrix enclosing quartz pebbles and fragments. On the opposite or north-east corner of the well the bed consists of a coarse sandstone

conglomerate, with some enclosed white quartz pebbles of large size. The calcareous rock thickens southward. The red sandstone is overlaid by whitish shales (5) much mixed up with kankar, which may be traced with difficulty for a few hundred yards northward, and are then completely hidden by cotton soil, which extends up to and far beyond the village of Mangamur (Mungamoor). In some well-sections south of the village, buffy brown sandy shales have been cut through under a bed of kankarry lateritic gravel. These shales establish the connection with some plant-bearing sandy shaly clays of drab-buff colour which are exposed near the head of a small stream a little to the north-west of the small hamlet called Kamapatte-varipalem (Kaumayputty-vareepully). The plant remains are unfortunately very fragmentary; but amongst them I recognised a small part of a *Ptilophyllum* frond; underlying the shaly clays, of which a thickness of 4 or 5 feet is seen, is a coarse friable micaceous sandstone of buff colour.

Section at Kamapatte-varipalem.

Rather more than a mile to the north of this section very similar buff and brown friable shales and sandstones show in the road drains and in various ballast pits, and in a few wells off the Ongole-Kambam high road, both on the slopes westward to the Santa Nuthalapad valley, and on the high ground to the eastward. The surface of the shales is thickly covered by yellow kankar gravel, mixed with lateritic pebbles. This yellow kankar descends deeply into the greatly weathered surface of the shale beds, not only here, but also in many other sections, so much so that the yellow colour of the kankar always led me to look out for underlying plant shales. The friable shale and sandstone beds extend north-eastward and northward from the high road down to the village of Yendlur, where they disappear under the great alluvial flat formed by the Mudigondi and Gundlakamma rivers.

Yendlur patch.

Yellow kankar overlying shales.

The high ground south of the high road was, at the time of my visit, covered by a very singular concretionary calcareo-ferruginous sandstone, often of jaspi-

Singular sandstone.

deous texture, the reddish yellow mass being largely permeated by minute silicious veinlets and threads of lighter colour. No organic remains could be traced in this strange bed, nor could its relations with the typical plant beds near-by be seen, owing to the great development of cotton soil around it. All that can be said of it is that it lay unconformably on the gneiss. When I first visited it in May 1875, it was being largely worked as revetment material for sundry tanks and wells; and by December of the same year I found that but very little remained to be carried away.

The *Vemávaram Budavada group*. Sections on the banks of the Gundlakamma.

A spread of alluvium, of 7 miles in width, lies between the southernmost point of the Yendlur patch of the Ongole group of plant beds and the nearest exposure of equivalent rocks belonging to the Vemávaram group which occurs on the north side of the Gundlakamma river at Gazulapadu, about a mile north-east of the travellers' bungalow at Velampalle (Valumpully).

The Gazulapadu section, which can only be seen when the river is quite low, shows very sandy kankarry clay, underlaid by orange and brown rather friable sandstone and grits, pebbly grits, and coarse conglomerate, all apparently part of one large variable bed. The conglomerate contains fragments of an old laterite; and a number of boulders of an identical rock are seen in one place resting on the clay bed just mentioned. The boulders are from 18 to 20 inches in diameter, and are themselves surrounded by the overlying alluvium, which here forms a considerable cliff.

The sandstones and grit bed can be traced all along the base of the alluvial cliffs from Gazulapadu to Kirtipadu (Keerteepaudoo), where it is hidden by a sandbank; but it re-appears again in the next reach of the river in the northern bank, and can be followed till nearly opposite Nandipadu (Nundeepaudoo), when it disappears.

Vemávaram patch.

Grey or brown sandy shales—true plant shales—are shown, by means of well-sections both east and west of Nidamanur, to occur below the thick cotton soil which there forms the surface. They

have also been turned up from a deep well sunk at Kavurupalem (Cavoororpalliam), 2 miles north-east of Nidamanur. Both these places lie within limits of the Vemávaram patch, the most important and most interesting exposure of the Rájmahál rocks in the Guntúr-Ongole country; but before proceeding to the full description of the rocks here met with, it will be better to refer briefly to three small and important patches lying at but small distances.

Small patches at Bolaveram, Chadulavadu, and Nagalupalapadu.

These are, *firstly*, the Bolaveram patch lying to the west, and the Nagalupalapadu (Nagooloopalapaudoo) and Chadulavadu patches lying respectively to the south-east and south-east-by-south.

The surface of the Bolaveram patch is entirely covered by the characteristic yellow kankar referred to as accompaying the plant shales in the Yendlur and other more southerly patches.

The Chadulvada and Nagalupalapadu patches are exposed only in solitary sections, the former in the bed of a tank a mile and a half east of the village, the latter in the great square *bowry*, or tank-well, east of the village. In both cases the rocks exposed consist of shales. These two patches of shale are separated from each other by a great unbroken spread of cotton soil underlaid by a low ridge of gneiss; but the cotton soil is so thick and continuous, that it is impossible to draw any boundary lines between the underlying rocks.

Vemávaram sections.

Of all the representatives of the Rájmahál rocks south of the Kistna, the beds exposed at Vemávaram (Womayaveram) are the most interesting and noteworthy, as they contain a larger number of both animal and vegetable remains, mostly in beautiful preservation, than any other beds met with elsewhere. The presence among the animal remains of *Cephalopoda* and *Echinodermata* establish the marine nature of the deposit beyond controversy.

The village of Vemávaram, close to which these plant-bearing marine beds are exposed, lies 14 miles north-east-by-north of Ongole, and 8 miles inland from the coast, on the eastern slope of a low bare

Figure 4. Diagram-section across Vemávaram ridge.

ridge of hard shale about three-quarters of a mile in length. The strike of the ridge is north-by-east to south-by-west. To the north-east and south it dies down under the great spread of cotton soil which locally covers the coast alluvium. To the south-west it sinks into a low neck of ground by which it is connected with a low broad-backed hill close to the village of Uppu Gundur (Ooppoo Goondoor), which also consists of beds of hard shale, which are nearly everywhere bare and devoid of soil and vegetation. The two hills form a peninsula jutting into the great alluvial plain. To the west the ridge is joined by a low neck with the western half of the Vemávaram patch.

Uppu Gundur hill.

The section given below shows the position of the beds seen in the central part of the Vemáva-ram ridge.

Details of section.

The beds shown in this section, which coincides with a low depression crossing the shale ridge a little to the north-west of the village, follow in descending order as below :—

8. Shales, purplish.
7. Do., buffy.
6. Do., softish, brown, white, and purple.
5. Do., hard, with red and brown sandstone partings.
4. Do., do., partly flaggy, with sandstone partings, variegated.
3. Do., thin, flaggy, rather hard, buff and white, "fish bed."
2. Do., sandy, mottled.
1. Sandstone, shaly, buffy.

Both the top and the base of the section are obscured by cotton soil, but rather more than 2 miles to the west, softish gritty sandstones appear from below the black soil.

The beds included in the section have a general low dip to the eastward, but they show also several small local rollings. The angle of dip ranges from 2° to 5° on the western side of the ridge, and 12° to 15° on the eastern side, close to the village. The section represents a distance of about 350 yards in length.

The colouring of the beds on the ridge varies frequently and within very short distances. Unfortunately, the shales are of no use economically, because of their breaking up into small pieces owing to the great number of joints traversing the beds; hence they are nowhere quarried, though other hard shales, which break into great flaggy pieces, are largely quarried at a little distance to the south. These latter unfortunately are poor in fossil remains of all kinds.

Fossils occur in all the shaly beds and are numerous in most, plants being rather less numerous than animal remains. The two classes of organisms constantly occur together in the same hand specimens. The most remarkable and about the best preserved fossils were obtained from the thin flaggy hard shale (No. 3 of the section) which, for brevity, I call the "fish bed." From this came doubtless the very interesting Eryon which I obtained on the occasion of my second visit in 1876. This macrurous crustacean, the first crustacean found in the Rájmahál rocks, which has since been specifically determined and figured by Dr. O. Feistmantel[1] as Eryon comp. Barrovensis, McCoy, is of special interest and importance as being the first case of identification with a European species of any of the animal remains as yet discovered in the marine beds of the Rájmahál series on the eastern coast of the peninsula.

The "fish-bed."

Eryon comp. Barrovensis not obtained at Sripermatur.

[1] Records of the Geological Survey of India, Vol. X, p. 4.
Note on "Eryon comp. Barrovensis," McCoy, &c., by Ottokar Feistmantel, M. D.

It was the discovery of this Eryon on a loose piece of shale that led me to look for the peculiar and, till then, unobserved bed it must have come from; by excavating I procured many of the finest and most important specimens collected at Vemávaram, including nearly all the fish remains obtained there. The missing parts of the Eryon could unfortunately not be found, though most carefully searched for.

By some mistake or other, Dr. Feistmantel has unfortunately described the Eryon as having been obtained from the Sripermatur group west of Madras, a series of beds which probably represent a rather higher horizon than at the Vemávaram shales. The error of locality is considerable, as the two places are rather more than 200 miles apart. The remarkable lithological similarity between the typical Sripermatur and Vemávaram shales must have contributed not a little to the possibility of such a mistake having been made.

The flaggy beds.

The highest known member of the Vemávaram group is a hard, coarse, white shale, breaking into large flaggy masses (which, as already mentioned, are largely quarried to the south of the village). They contain a few, mostly ill-preserved, fossils, consisting of undeterminable stalks of plants, of bivalve shells allied to Leda, and of thin-shelled Ammonites, too much flattened by pressure for satisfactory determination of their specific characters. These coarse shales occur to the south-east of the Vemávaram section first described, and would, if that section were extended sufficiently to the east, be seen to lie above, and probably immediately upon, the purplish shales No. 8, though it is possible that a small thickness of finer grained whitish shales might intervene.

Flaggy beds at Razpudi.

Very similar coarse flaggy shales form a thick bed exposed in numerous quarries close around the village of Razpudi, a little more than a mile north of Vemávaram ridge. They are very likely a continuation of the Vemávaram flags, the only difference they show being in colour, which is not pure white, but white variegated with delicate bands of red, pink, mauve,

purple, and occasionally orange, arranged concentrically, and presenting surfaces of no little beauty of colour. The form of those patterns on the shale vary considerably, as they are generally confined between the limits of a set of joints to which the concentric curves show a clear relation. Some examples were noticed several feet in diameter, others only a few inches, but these latter were generally independent of any visible joints. No Ammonites were found in the Razpudi bed, but the other fossils agreed with those from the Vemávaram flags, and, like them, are ill-preserved, many being blurred by an incrustation of extremely minute quartz crystals. Fragments of *Dictyozamites* and *Ptilophyllum* were the only recognizable plants met with at Razpudi.

Their colour.

Fossils found at Razpudi.

In their mode of preservation and condition of occurrence, the Vemávaram fossils agreed very closely with those obtained at and near Sripermatur. In the great majority of specimens the impressions or casts are stained of some colour different to that of the enclosing shale.

The colour, which is generally some shade of red or purple, more rarely black or brown, is in most cases confined to the organism which, for that reason, contrasts strongly with the matrix. The plant remains are all fragmentary, many of them very much so, showing that they must have been washed out to sea as torn-off leaves or fronds, but speedily embedded, as they show no signs of decay. The shells are frequently crushed by pressure supervening after they were buried in the mud, but very few show signs of previous injury, and in a very large percentage the two valves of the pelecypodous shells remain in opposition, showing that the living animal had not been brought hither from any great distance, but was rather an inhabitant of the place where entombed, or of its immediate vicinity. As in the Sripermatur beds, the character of the most common shells indicates that the shales were deposited in a rather shallow tranquil sea.

Fossils at Vemávaram. Colour, &c.

Condition of preservation and its indications.

List of fossils found.

The following list of the organic remains, both vegetable and animal, shows their nature, but only in a preliminary manner, as complete lists can only be drawn up after close examination of the entire collection now in the Museum at Calcutta. The list of animal remains, indeed, must be accepted merely as a rough field list, as no opportunity offered for any close examination or comparison before the collection was shipped to Calcutta.

Further examination and excavation of the shales will doubtless add very considerably to the number of fossils now known to occur in the Vemávaram beds.

PLANTS.	ANIMALS.
Fucoida ? 2 sp. ?	Rib, impression of, ? mammalian.
Sphenopteris, sp.	Fish, 2 or 3 species ?
Dicksonia, sp.	Do. scales, cycloid.
Cyclopteris ? sp.	*Eryon* comp. *Barrovensis*.[1]
Alethopteris indica.	*Ammonites.*
Angiopteridium spathulatum.	*Belemnoteuthis*, sp. conotheca, crushed.
Macrotæniopteris ovata.	Gasteropodous shell, impression of.
Do. sp.	*Inoceramus.*
Pterophyllum distans.	*Pecten.*
Do. sp.	*Exogyra.*
Do. *fissum.*	*Leda*, 2 or 3 species ?
Zamites proximus.	*Tellina*, do. ?
Ptilophyllum acutifolium.	*Yoldia*, do. ?
Do. *cutchense.*	*Lithophagus*, sp., burrows of.
Otozamites, sp.	? sp., a broad shell quite crushed.
Dictyozamites indicus.	*Terebratula ?*
Palissya indica.	*Eschara.*
Chirolepis ? sp.	*Ophiura*, 2 species or varieties.
Echinostrobus rajmahalensis.	
Araucarites, sp. (*? macropterus*).	
Cunninghamites dubiosus ?	
Coniferous leaves undetermined.	
Stalks, seed-vessels, &c., &c.	

[1] Since determined specifically by Dr. Feistmantel. Records, Geol. Surv. of India, 1877.

The *et cetera* includes at least three more undetermined plants of whose botanical affinities I was in doubt, but could obtain no solution from the books of reference at my command. The stalk-like remains also probably include several species yet to be determined, as they show considerable variety of marking and branching.

Uppu Gundur beds.

Though similar in general appearance to the Vemávaram beds, the Uppu Gundur beds differ in being generally very poor in fossils. The most important fossils found here were a few Ammonites of small size, but unfortunately they are too much crushed for specific determination. Owing to the great sheet of cotton-soil between the two hillocks, the real relationship between the several beds composing them cannot be determined positively, but the probability is, the Uppu Gundur beds overlie the Vemávaram shales. As before mentioned (page 64), the coarse flaggy ammonitiferous shale exposed in small quarries between the two hillocks must be looked upon as a southern extension of the Razpudi flaggy beds. The beds on the hill are in parts horizontal; to the north-east and east they dip correspondingly, and they also make a slight roll to the west. They are more massive than the beds on Vemávaram ridge.

To the west of Vemávaram ridge, cotton-soil covers everything thickly, till the ground rises again beyond the old Madras-Guntúr road.

Shales at Pyindipad.

Barely perceptible traces of the plant-beds are seen eastward of Kallagumta. A little gritty sandstone is seen at Kistarazpalem, but at Pyindipad sandy shales and friable sandstones are cut through in several well-sections. No fossils were seen in these beds, which are underlaid to the north-westward by brown gritty sandstones, which show close to the boundary of the gneiss, on which they doubtless rest.

Annavallawarpalem sandstones and clays.

South of Pyindipad tank is a band of hard gritty sandstone extending from the east end of the Annavallawarpalem tank north-eastward nearly to Kistarazpalem. No fossils were seen in this sandstone, which is of varying colours, ranging

from dark blackish-brown to grey or drab. It rests upon the granitoid gneiss close to Kallagumta village. South of the hard sandstone, and probably overlying them, come soft friable gritty sandstones and shaly clays. The latter are of drab colour, the former orange to reddish or drab, and full of impressions, in bright red, of fragmentary plant-remains, amongst which the pinnulæ of a small variety of *Dictyozamites indicus* are most commonly recognizable, *Ptilophyllum acutifolium* being also present, but much less common. The dip of these beds is westerly from 3° to 5°. A little further south still are coppery-red mottled sandy clays, with orange to reddish-brown gritty sandstone, lying close to, or actually on, the gneiss.

Plant-remains in shaly clays.

A shallow alluvial valley, nearly 2 miles across, divides the Vemávaram patch from the next northern patch, which lies around the village of Nucherlapalle (Noocherlapally). The beds here seen in well-sections are white and mottled shales, very like the Vemávaram ridge beds; but, unlike these, they are very poor in fossils, a long search only yielding a single specimen,—a thin, broad, bivalve shell, crushed flat by pressure, of a species very common at Vemávaram. The beds show a dip of from 10° to 15°, to east-by-south. Sandy shales are seen in a small field well, about a mile to the westward, near to the gneissic boundary.

Nucherlapalle patch.

The next patch of Rájmahál rocks, proceeding northward, is the Budaváda (Boodhawadah), the southern point of which lies 3 miles to the north-north-east, near Gangávaram, where shaly buff sandstone is seen in well-sections west and south-east of the village. Similar shaly sandstones and sandy shales begin to appear in small field sections as the village of Budaváda is approached from the south, and in the bottom of a tank lately constructed about half a mile east-by-south of the main village. Here a few score square yards of shales were to be seen when the tank bottom was dry; they are underlaid by, or intercalated with, friable soft sandstone, also of whitish to

Budaváda patch.

Shale bed east of Budaváda.

yellowish-drab colour. Both contain fragmentary plants and small sea-shells. The plants and shells found were as follow :—

PLANTS.	ANIMALS.
Dictyozamites indicus.	*Ammonites* sp., crushed.
Pterophyllum sp.	*Pecten* 2 sp.
Ptilophyllum cutchense.	*Leda ?*
Do. acutifolium ?	*Avicula.*
Palissya indica ?	Fish scales, cycloid, very thin.

These beds represent No. 6 of the section given below.

Budaváda section.

Underlying these soft sandstones and shales is apparently a set of sandstones on which stands the village of Budaváda, and overlying them is another set of sandstones on which the village of Pávulur has been built. The relation of the several beds is best explained by the accompanying ideal section from Budaváda to Pávulur.

Fig. 5. Ideal section from Budaváda to Pávulur.

The section begins half a mile west of Budaváda, at the gneiss boundary, runs due east for the first half of its length, and then turns north-east up to the village of Pávulur, the total length being two and a half miles.

The beds here seen fall naturally into a triple grouping, thus :—

	10. Lateritic gravel.
Pávulur group ...	9. Sandstones, friable, coarse, reddish-brown.
	8. Sandstones, hard, greenish or bluish-black, calcareous, slightly shaly, weather grey or brown.
	7. Sandstones, friable, drab pale brown.
Vemávaram group ...	6. Shales, various, hard and soft, mottled in parts, generally whitish or light grey in colour.

Budaváda group ...	5. Sandstones, gritty, calcareous, full of shells, rather hard and tough when fresh.
	4. Sandstones, shaly, friable, dark-buffy.
	3. Sandstones, hard, brown, alternating several times with thin shaly beds.
	2. Sandstones, massive, hard, brown.
	1. Sandstones, pebbly outcrop, much weathered.
	Gneiss.

The general dip of these beds is easterly, at varying and mostly low angles. Beds Nos. 4, 5, 6, and 8 contain marine shells; Nos. 5 and 6 contain plants as well, and No. 9 plants only.

The shales No. 6 represent, I believe, the Vemávaram shales, from parts of which they do not at all differ, while they have a strong resemblance to many of the shales in the Utatúr patch of plant-beds in Trichinopoly district. They are best seen in well-sections to the west and south-west of Nakkalapalem and north-west of Pávulur.

The shelly calcareous sandstone No. 5 is quite unlike any known member of the Rájmahál series throughout India. Unfortunately, what little remains of the bed is very badly exposed, and its relations to the under and overlying beds are consequently obscure. Most of the bed had been quarried away when I first visited Budaváda; what little remains is to be seen at the western side of the village, just south of the end of the main street, and in a few wells south of the village close to some old indigo works. This remarkable bed was probably a drifted accumulation of shells deposited in discontinuous lenticular patches of limited extent. The matrix is generally gritty, but here and there clayey.

The Budaváda section seems to take in the whole of the Rájmahál series in this region, but owing to the great and continuous spread of cotton soil, which covers the face of the country generally, parts of the section are by no means clear, and I offer it with some hesitation, as other observers might draw different conclusions from the data available. It is constructed from the examination chiefly of a series of well-sections supplemented by a few poor outcrops and small quarries.

Budaváda "shell bed."

The shelly sandstone No. 5 is extremely rich in fossils; indeed in many parts the whole mass almost consists of shells, broken or entire as the case may be. The plant remains it contains are very rare, and only one specimen of a Bryozoon was found. No other fossils were found. The following list of the specimens collected must be taken as purely preliminary, a rough field list in fact:

PLANTS.

Ptilophyllum acutifolium.	*Angiopteridium spathulatum.*
Otozamites sp.	Undetermined leaflets and small woody fragments.
Dictyozamites indicus.	

ANIMALS.

Ammonites	sp. ? 2 sp.	*Pecten,*	3 sp. ?
Buccinum	sp. ?	*Lima*	sp.
Natica	sp.	*Plicatula*	sp.
Cerithium	sp. ?	*Avicula*	sp.
Turritella	sp. ?	*Modiola*	sp.
Eucyclus	sp. ?	*Yoldia*	sp. ?
Turbo	sp. ?	*Trigonia*	sp. ?
Trochus	sp. ?	*Cardium*	sp. ?
Patella	sp., large, broad.	*Astarte*	sp. ?
Do.	sp. „ high.	*Mactra*	sp. ?
Do.	sp., small, radiately ribbed.	*Myacites*	sp.
Rhynchonella	2 or 3 sp.	*Gresslya*	sp. ?
Terebratula	? 2 sp. ?	*A bryozoon.*	
Ostrea	3-4 sp. ?	*Serpula*	sp.

Condition of the fossils.

The plant remains, which, as already mentioned, are of rare occurrence, were, with one or two exceptions, all obtained from one mass of the stone which was unusually clayey in character. They are sufficiently well preserved to be easily determinable.

Some of the best specimens, especially of the large Patellas, were broken out of masses that had been used in the walls of the furnace under the boilers in the old indigo factory, and show strong indications of fire action, approaching calcination, being much reddened or blackened, and having become much more brittle than the unburnt specimens.

Numerical ratio of species.

The most numerously developed species are the *Ostreidæ*, then the *Terebratulæ* and *Rhynchonellidæ*. The Ammonites are fairly numerous, but mostly fragmentary. Of the Gastropoda, the *Patellidæ* are the most remarkable, both for number and great size, but unfortunately most of the specimens are in poor preservation. Three, if not four, species are recognisable among them. Many of the shells were imbedded in a broken condition.

Pávulur sandstones.

No determinable fossils were found in the Pávulur sandstones *in situ;* those seen were extremely minute fragments of shells, but little larger than the grains of sand they are associated with. Fossils of recognisable character were, however, found in a number of blocks of coarse calcareous sandstone forming part of the revetment of the bund of a little field tank about half a mile north-east-by-north of Budaváda village.

Calcareous sandstone of uncertain origin.

Unfortunately, these blocks could not be traced to their original sites. None of the contained fossils could be identified with true Budaváda species, and the blocks themselves bear no resemblance to either the Budaváda or Pávulur rocks. According to the villagers they had been brought from the Pávulur quarries, but no similar stone could be traced by me; their origin must, therefore, remain uncertain.

The calcareous sandstone forming these blocks is very hard and exceedingly tough, and the fossils very hard to extract.

Its fossils.

The following list is a rough determination of the few that I succeeded in getting after much severe labour:—

Belemnites sp., small
Cerithium sp.
Turbo sp. ?
Patella sp.
Rhynchonella sp.
Cardium sp.
Ostrea sp.
Lithodomus bores in Ostrea.
Small bivalves undetermined, several.

These Belemnites are the only South Indian representatives of the genus that have been collected outside of the cretaceous areas in Trichinopoly and south-west districts. Not the faintest trace of plant-remains accompanied the shells.

Nautilus.

Unconnected with any of the rocks named in the list descriptive of the Budaváda section is part of a large Nautilus that I picked up loose in the fields about three-quarters of a mile east-by-south of Budaváda village. This specimen, which shows part of the body chamber of a good-sized individual, cannot be referred to any of the known rocks of that locality, and is unfortunately too fragmentary to admit of satisfactory specific determination. A long and careful search failed to throw any light on the origin of this interesting specimen, the only representative as yet of the genus Nautilus in the Rájmahál beds of the Peninsula.

Pávulur plateau.

The Pávulur sandstones Nos. 7, 8, and 9 of the section form, as there shown, a small plateau approximately circular in shape and about a mile and a quarter in diameter. The thickness of this Pávulur group is small, but all the members not occurring together in any one section, the total thickness is doubtful. The beds roll about a little at low angles, but are here and there quite horizontal. The hard dark-coloured slightly shelly bed No. 8 is from 2 to 3½ feet thick. The underlying drab sandstone was not pierced by any of the pits open at the time of my visit, but is probably not more than 5 or 6 feet thick, according to the quarrymen and the owner of the ground, which agrees with the estimate I formed independently. Some of the blocks of the dark sandstone, of irregular shape, and covered externally with a brown weathering crust, have at the first glance a singularly trappean look, and I was for a moment startled by the idea that I had come upon a bedded trap.

The drab sandstone No. 7 contains some intercalated flatly lenticular masses of hard dark sandstone, similar to that in the overlying bed. The latter dips gently eastward near the village of Pávulur, and is here apparently overlaid by the friable reddish-brown sandstone No. 9, which

contains numerous obscure fragments of plants of red colour very similar to those observed at Annavallawarpalem in the Vemávaram patch. Obscure vegetable remains occur also occasionally in the lowest member of the Pávulur group, the drab sandstones No. 7.

Eastern part of Budaváda patch.

In the eastern part of the Budaváda patch no natural exposure of the Rájmahál beds was met with, and they are revealed only in a few well-sections to the east of Pávulur, at Inkolu (Yinkolu) and a little distance to the south-west of Hanumazipalem. In all these the rock shown consists of soft sandy shales of buffy colour containing few or no traces of plant-remains.

Idupulapadu patch.

In proceeding northward from the Budaváda patch of Rájmahál beds, we find it to be separated from the Idupulapadu patch by a flat alluvial valley a little more than a mile in width. The plant-beds form a broad low whale-backed spur a couple of miles wide from north to south, and about 6 miles long from west-by-north to east-by-south. Here also nearly the entire surface is covered by cotton soil so thickly that but very few exposures of the Rájmahál rock can be found. Only two genuine exposures were seen, the one a little to the west of Idupulapadu village, the other just north of Ambatampudi hamlet on the southern boundary of the patch close to where it is crossed by the path leading from the above-named village to Nakkalapalem and Budaváda. Both these exposures are too slight in depth to afford a section of any value, and no other information was procurable than from well-sections in the fields. In many of these, too, only the dug out material was available, the sides of the wells being inaccessible. Enough was seen to ascertain that the whole patch is made up of grey and white and rusty-brown mottled shales, which are doubtless an extension of the shale beds No. 6 north and north-east of Pávulur, which I regard as in their turn an extension of the Vemávaram beds. Fossils were found in two or three of the well-sections west of

Fossils at Idupulapadu and Dronádula.

Idupulapadu, and in one section in the fields belonging to Dronádula (Deranadula), about a mile and a half south-east of the village. The fossils found, which

agree in type and mode of preservation with those from the Vemávaram beds, were as follows :—

FROM IDUPULAPADU.

Plants—
- *Dictyozamites indicus.*
- *Pterophyllum* sp.
- *Alethopteris indica.*
- *Equisetum ?*
- *Otozamites ?*

Shells—
- *Pecten* sp.
- *Pleurotomaria* sp. ?
- *Dentalium* sp. ?

and several obscure ill-preserved bivalves.

FROM DRONADULA.

Plants—
- *Dictyozamites indicus.*
- *Ptilophyllum cutchense ?*
- *Do. acutifolium.*
- *Angiopteridium spathulatum.*
- *Araucarites macropterus ?*

Shells—
- *Ammonites* sp., fragt.
- *Astarte* sp. ?
- *Yoldia* sp. ?

In several cases the plant-remains and shells were found side by side in the same pieces of shale. All the plant-remains are very fragmentary, but otherwise they are well preserved and easily distinguishable.

The beds roll about to some extent at various but generally low angles.

Yellowish buffy sandy shale underlies the cotton soil and lateritic gravel near the eastern extremity of the Idulapadu patch, but is only exposed in a well-section, which lies about three-quarters of a mile east-south-east of Duggubadu.

A very small patch of Rájmahál beds separated from the Idupulapadu patch by the alluvium of the Dronádula nullah occurs immediately north-east of the latter village. It is separated to the north by another strip of alluvium from the large Punur patch of Rájmahál rocks.

The Punur patch.

As shown by the map, the Punur patch is of very irregular trilobed shape, but of considerable size. Like the other patches, it rises but little over the general level of the alluvium, and is almost everywhere thickly covered by cotton soil, and the sub-rock is exposed only in artificial sections. The largest exposure of the rocks is seen in the bottom of the tank south of the village

of Punur, where mottled shales, precisely similar to those occurring to the south-east of Dronádula and west of Idupulapadu, have been cut into about a couple of feet, and used in strengthening the tank mud. A cursory examination of these shales, which are moderately rich in organic remains, yielded—

Punur tank section.

PLANTS.	ANIMALS.
Dictyozamites indicus.	*Astarte* ? } very minute.
Ptilophyllum acutifolium.	*Yoldia* ? } very minute.
Pterophyllum sp.	

West of the village the shales become more sandy in character and appear to pass into, or are replaced (underlaid) by friable sandstones which must rest upon the gneiss. Buffy friable sandstones are exposed, but very badly, in well-sections in the northern lobe of the Punur patch, at the villages of Gannavaram and Yanamaduli.

Shales replaced by sandstones west of Punur.

The Gannavaram sandstone contains a great quantity of highly decomposed granite gneiss, and is very clayey. In the north-eastern lobes of the patch, buffy friable shaly sandstones are exposed under thick cotton soil, and some lateritic gravel in several well-sections between the villages of Zagarlamudi and Tanubudivarípalem.

The Punur shales extend fully a mile and a half north-eastward of the exposure in the tank bottom just referred to, and have been turned up in the bund of a small tank by the side of the road to Polur. White stiff mottled fine-grained sandy shales have also been cut into in making the bunds of the tanks at Vankoelupadu and Nutalapadu in the eastern lobe of the Punur patch.

Northward of the Punur patch comes a spread of alluvium which hides all the Rájmahál rocks for a distance of 11 or 12 miles. The first patch of the jurassic beds to be found here occurs at Kopparu, which stands at the northern end of a peninsula-like spur of slightly raised ground stretching south from the southern end of the Kondavidu hills.

The Guntúr group.

Kopparu patch.

The beds here exposed in various wells are sandy shales and thick-bedded friable buffy sandstones, apparently containing no organic remains. Similar friable sandstones occur (also in well-sections) under lateritic gravel a little to the east and north-east of Karchola (Kartibola). That these beds and others associated with them extend further eastward under the alluvium is proved by the fact that similar beds, typical sandy shales, and white and mostly mottled clayey shales are penetrated by the deeper wells sunk through the overlying thick cotton soil and lateritic and kankarry beds at Gorizagoluguntapalem and at Ravipadu, lying respectively 2½ and 4½ miles east-north-east of Kopparu. These sections indicate the junction of these beds with similar beds in the two Rájmahál inliers of Chebrolu and Tangellamudi, on the western border of the Kistna delta.

Shales at Ravipadu, &c.

Returning to the westward we shall find pale buffy shaly sandstone and sandy shales underlying lateritic gravel at Chinna Kondrapadu, 10 miles south-west of Guntúr.

The next sections of Rájmahál beds to be noticed occur at Guntúr itself, where coarse, friable, gritty, pebbly sandstones are exposed in various well-sections in the western part of the town. These gritty beds consist entirely of gneiss debris. The best section is afforded by an old unwalled bowrie (square well) close to the north gate of the compound belonging to the Judge's house. About 12 feet of friable gritty sandstone of extreme coarseness, locally quite a conglomerate, and penetrated by large numbers of kankar veins running in various sets, is here seen. One chief set of these kankar veins appears to indicate the true dip of the otherwise unstratified bed. The dip, if it be thus really indicated as supposed, is south-easterly at a low angle. No signs of any organism could be seen. A similar but much deeper and totally inaccessible section is to be seen close by in a large well sunk by Mr. John Rohde, C.S., when Judge of Guntúr.

Soft grits at Guntúr.

Sections at west end of town.

Similar gritty sandstone was turned out in small quantity from the bottom of the municipal filtering tank at the north end of the great irrigation reservoir known as the Black Tank.

Chebrolu and Tangellamudi inliers.

Separated from the Guntúr sections by a band of alluvium varying from 5½ to 9½ miles in width are the two Rájmahál inliers, already referred to several times, of Chebrolu and Tangellamudi. These two inliers form a low but well-marked ridge running 14½ miles through the alluvial flat in a very nearly due north-east-to-south-west direction, with only one break through which flows the Guntúr nullah, which falls into the "Old Tungabhadra," the most westerly branch of the Kistna in the delta. The ridge has an average width of about 2 miles, roughly speaking. It is the more conspicuous from being generally covered with red sandy soil, which contrasts strongly with the dark black regur which covers the surrounding alluvium flat.

No good sections to be found.

Here, as elsewhere in this region, no satisfactory section is to be found showing the relation of the various rocks composing the inliers, and considerable uncertainty exists about their stratigraphical position.

Tangellamudi inlier.

A friable gritty sandstone, in many respects a good deal like the Guntúr beds, is exposed in a new well to the south-west of Kolakalur, at the extreme north end of the Tangellamudi inlier. The relation of this to the reddish and purplish, hard, gritty sandstones at Tangellamudi, and the soft and purple mottled sandstones at Kazipett (Khabampeta), is quite problematic, and there are no intermediate sections to throw light on this point, for, in the three-quarter mile distance between Kazipett and Kolakalur and the 2½ miles between the latter place and Tangellamudi quarries there is room for a variety of changes of position. Similarly, in the Chebrolu inlier it is quite doubtful whether the hard sandstones forming the northern half of the inlier lie under or over the soft shaly beds forming the southern half. In this case, however, I was able to form the conclusion that the hard

beds are the newer, as they are at the Pávulur end of the Budaváda section (see *ante*, page 69), but with regard to the Kolakalur soft gritty bed, I feel very doubtful what to think, though inclined to regard them as newer than the hard beds.

The Tangellamudi sandstones have been quarried for centuries probably, and great part of the bed removed in consequence.[1] The sandstones are best seen south-west of Tangellamudi and west of Shekur, where they can still be traced as a continuous bed, but much cut up by jointing, especially where the purple colour prevails. The beds roll about considerably, chiefly to the north-east and north-west. From 6 to 7 feet in thickness of rock is exposed, but the underlying beds are not seen anywhere. The prevalent colours of the sandstone are reddish and purplish-brown, ranging to positive purple with yellowish-buff stains. Much quarrying is now going on, there being a large demand for the stone for many purposes.

The Chebrolu inlier.

In the Chebrolu inlier the sandstones are best seen in the pits near the old trigonometrical station, 3 miles north by east of Chebrolu, and in those immediately north of the village. In the former from 9 to 10 feet of rock only is seen *in situ*, and it is mostly of purple colour, with white spots; but buff and purple mottled and purely buff colours are also to be found. The surface of some beds is formed by a thin layer of small pebbles.

The sandstone underlying the lateritic gravel close to Chebrolu is a fairly massive compact gritty rock of purple, brown or reddish colour, tolerably thick bedded, and the beds generally pretty level. From the lie of the ground I infer that these hard sandstones overlie the friable mottled purple (or red) and white sandstones exposed to the south of Gundavaram village 1½ miles to the north-west of Chebrolu.

Sections at Mutlur.

To the south-west of Chebrolu, where the ridge begins to sink, it is covered by cotton soil instead of red soil, and every thing is obscured till the village of Mutlur

[1] The Tangellamudi quarries appear to have been used by the Jains, for beautifully carved specimens of the sandstones, evidently taken from an old Jain temple, have been built into some of the walls, *e. g.*, the northern gate, of the great hill fort of Kondavidu.

(Mutnur) is approached, where a number of well-sections show the nature of the underlying rock.

In a well east of the road to Chebrolu and a little to the north of Mutlur the following section is seen:—

4. Alluvium.
3. Sandstone, friable, buff } 6 feet.
2. Sandy clay ... }
1. Clay white (slightly mottled yellow, red and dark-grey).

The white clay is chiefly below the water-level. The beds appear to dip east-by-north, at 5°.

On the highest ground more to the north of the village, several wells show rather friable gritty sandstones of pale mottled buff pink and purplish colours; lateritic gravel 2′-5′ thick rests upon these.

To the west and south-west of the village the sandstones have a southerly dip, and the thickness of the lateritic gravel overlying them increases up to 8 or 10 feet. None of the beds at Mutlur yielded any fossils, though they were carefully examined.

Ippatam conglomerate.

The last case of rocks that might possibly be referred to the Rájmahál series must now be mentioned. It occurs at Ippatam, 4½ miles south-by-east of the southern end of the Bezwada anicut, and 3 miles east-by-north of Mangalagiri, where a very small patch of coarse conglomerate, resting on the gneiss, disappears eastward under the alluvium of the delta. This conglomerate consists of pebbles of quartz, some of gneiss and a few of quartzite, united by a lateritic matrix showing true vermicular cavities, where the included pebbles are not very numerous. The bed dips at from 3° to 5° to east, and about 30 feet in thickness of it is exposed. No fossils were seen in it, so its age can only be inferred on other grounds. On petrological grounds it is not assignable to the Rájmahál beds, though its stratigraphical position is suitable. Petrologically it differs greatly also from the ordinary lateritic formations of the surrounding country, nor is there any stratigraphical connection with closely adjoining lateritic

gravel which contains chipped stone implements. The great coarseness of this conglomerate and its stratigraphical position both unite in suggesting that it may be of the age of the immensely coarse Rájahmundry conglomerates, recognized by Mr. King as equivalents of the Cuddalore sandstones. The only difficulty in regarding the Ippatam conglomerate as representative of the Rájahmundry beds, lies in the considerable distance between the two formations without any intermediate link.

Correlation of the Guntúr group with the Vemávaram Budaváda group.

It will have been seen in the foregoing pages that the beds which may, with good reason, be regarded as extensions of the Vemávaram group can be traced northward from Vemávaram for a distance of more than 20 miles, and the evidence of the fossils obtained at Budaváda, Dronádula, and Punur quite confirms the deduction made on stratigraphical and petrological grounds. Beyond this point petrological resemblance is the only guide in correlating the different groups of Rájmahál rocks that have been met with in the Guntúr country. The petrological resemblances to the southern rocks found in these northerly patches justify the assumption that the triple sub-division found to hold good in the south may reasonably be extended to the north. The sandstones of Kartichola and Kopparu, and the gritty beds of Guntúr, may be fairly classed with the sandstones of Annavallawarpolliam, Budaváda, Punur, and Gannávaram; while the shales of Ravipadu, Gorizagoluguntapalem, and Mutlur represent the Vemávaram shales, and the purple sandstones of Chebrolu and Tangellamudi represent the dark sandstones of the Pávulur group.

Correlation of Guntúr-Ongole Rájmahâls with Godávari Rájmahâls.

The Upper Gondwána beds occurring north of the Kistna have been similarly divided by Mr. King (Records Geological Survey of India, Vol. X, page 56; 1877) into three sub-divisions called respectively the—

Tripetty sandstones.
Ragavapuram shales.
Gollapilli sandstones.

Not practicable.

Whether this triple grouping will fit in with the triple division made out by me in the Upper Gondwánas south of the Kistna, remains to be seen when all the fossils from both regions have been fully worked out; but I think it is very doubtful. From the preliminary examination of the fossils, Mr. King and Dr. Feistmantel incline to consider the Ragavapuram shales as the equivalents of both the Vemávaram group of the Guntúr-Ongole region and the Sripermatur group of the Madras region. Dr. Feistmantel regards the Ragavapuram beds as equivalents also of the Utatúr plant beds of the Trichinipoly district.

My present view on this subject is, that the Vemávaram shales are not exactly the equivalents of the Sripermatur group, and therefore also not exactly equivalent to the Ragavapuram shales, but are of rather greater age, and represent the Golapilli group, and *may therefore be regarded as true marine equivalents of the typical Rájmahál beds of Bengal.* Dr. Feistmantel has, in his description of the flora of the Golapilli beds, in the Palæontologia Indica,[1] stated his belief that the Utatúr, Sripermatur, and Ragavapuram plant-beds are younger than the true Rájmahál beds. He groups the Vemávaram shales in the same category; but at the time he stated this, he was, owing to an unlucky confusion of the collections from Sripermatur and Vemávaram, under the impression, strongly supported by the similarity of the two sets of shales, that both came from the same region.

Comparison of Vemávaram and Golapilli fossils.

Judging the case by the evidence of the fossil plant-remains, it appears to me that the Vemávaram shales show a facies distinctly older than that of the Sripermatur group, and contain a greater number of characteristically Rájmahál plants than do any of the other plant-beds in the peninsula, Mr. King's Golapilli sandstones excepted. This view is borne out by a comparison of the Golapilli plants as compared with those obtained from the Vemávaram shales. The list of Golapilli plants I take

[1] Ser. II, 3, p. 8.

from Dr. Feistmantel's Notes on the Fossil Floras of India, No. II[1]; that of the Vemávaram fossils from my Notes on the representatives of the Upper Gondwána series.[2]

GOLAPILLI.

Alethopteris indica.
Asplenites macrocarpus.
Gleichenites bindrabunensis.
Angiopteridium spathulatum.
Ditto ensis.
Pterophyllum morrisianum.
Ditto carterianum.
Ditto comp. distans.
Ptilophyllum acutifolium.
Ditto cutchense.
Dictyozamites indicus.
Williamsonia sp.
Palissya pectinea.
Ditto oldhami.
Echinostrobus sp.
Araucarites sp.

VEMÁVARAM.

Sphenopteris sp.
Dicksonia sp.
Cyclopteris ? sp.
Alethopteris indica.
Angiopteridium spathulatum.
Macrotæniopteris ovata.
Ditto sp.
Pterophyllum distans ?
Ditto sp.
Ditto fissum.
Zamites proximus.
Ptilophyllum acutifolium.
Ditto cutchense.
Otozamites sp.
Dictyozamites indicus.
Palissya indica.
Cheirolepis ? sp.
Echinostrobus rajmahalensis.
Araucarites macropterus ?
Cunnighamites dubiosus ?
Coniferous leaves, undetermined.

It will be seen from these lists that, out of the sixteen forms described from Golapilli, eight, if not nine, are also found in the Vemávaram beds; and of the eight common to both series, five occur numerously at, and are characteristic of, the Vemávaram series. These are *Pterophyllum distans, Ptilophyllum acutifolium* and *cutchense, Dictyozamites indicus* and *Echinostrobus rajmahalensis.* In a private letter I received on this subject some little time since from Dr. Feistmantel, he dwells on the absence from the Vemávaram beds of the broad fronded *Macrotæniopteridæ:* this is true; but it is an objection which applies equally to the

[1] Records Geol. Surv. India, Vol. IX, p. 89, 1876, and Pal. Ind. Ser. II, 3.
[2] Records Geol. Surv. India, Vol. XI, p. 259; 1878.

Golapilli beds. If the large *Macrotæniopteridæ* are wanting at Vemávaram, per contra we have a far larger development of the pre-eminently Rájmahál genus *Dictyozamites* than at Golapilli or anywhere else out of the Rájmahál hills. The Vemávaram *Dictyozamites* may have to yield the palm in point of mere size to some of the specimens from Amrapura, in the Rájmahál hills, figured by Oldham and Morris in plate XXIV of Series II of the Palæontologia Indica; but several of the fronds I collected (at Vemávaram) were in every other respect far more perfect, and quite as beautifully preserved. Although I cannot accept Dr. Feistmantel's and Mr. King's views, that the Vemávaram shales are the exact equivalents of the Ragavapuram and Sripermatur shales, I quite agree to their idea of the equivalency of the two last named groups, and regard them as younger than both the Golapilli and Vemávaram beds.

The most characteristic plants of the Sripermatur group are *Ptilophyllum acutifolium* and *cutchense*, and a conifer that agrees with none as yet figured from the typical Rájmahál beds. *Angiopteridium spathulatum* is also a by no means uncommon plant at Sripermatur, and it cannot be reasonably contended that the Sripermatur and Vemávaram groups agree in the facies of the fossil plants they contain, but rather that they differ considerably, more so, indeed, than do the Vemávaram and the Utatúr plant-beds.

No division of the members of the Rájmahál beds in the Ongole and Kandukur groups was found practicable.

CHAPTER V.—CUDDALORE (RAJAHMUNDRY) SANDSTONES.

Ippatam conglomerate.

The rocks to which the above title is applicable, if they occur at all within the Guntúr-Ongole region, are developed but to a very small extent, and only in one spot, close to the Kistna. This one spot lies near the village of Ippatam, 4½ miles south-by-east of the Sitanagaram end of the great anicut. Here occurs a small patch of immensely coarse conglomerate, with

a lateritic matrix, which conglomerate has already been referred to and described when treating of the Upper Gondwána rocks (see page 80). As there stated, nothing but speculation can be advanced as to the real position of the small patch of conglomerate which differs so greatly from all the other formations within the area of this memoir, no clear evidence, whether palæontological or stratigraphical, being available. The petrological evidence amounts to a mere probability, but a very reasonable one, that this patch of conglomerate may be an outlier of the once far more widely extended Rajahmundry conglomerates. These conglomerates are regarded by Mr. King as northern equivalents of the group established in the south by Mr. H. F. Blanford, as the Cuddalore Sandstone.[1]

CHAPTER VI.—THE LATERITIC ROCKS.

The formations that have to be grouped under the above heading cover a not inconsiderable space in the Guntúr-Ongole region, but they are mostly thin superficial deposits, and really of small importance, but that in parts they give character to the general surface of the country. As already mentioned, they form part of the band of sedimentary rock which generally lies between the old gneissic rocks and the recent coast alluvium. In addition to the areas shown in the map, this group must include sundry patches and remnants of patches of shingle, mixed or unmixed with lateritic particles, which are scattered in various parts over the surface of the older rocks, especially the gneiss. From their exceedingly irregular (ragged) shape and want of definition of boundaries, these shingle patches could in hardly any cases be satisfactorily mapped, but their presence has been indicated on the Atlas maps, either by writing the words "shingle" or "gravel," or by a special mode of marking; on the reduced skeleton map attached to this paper, most of these small patches had to be omitted.

[1] Memoirs Geol. Surv. India, Vol. IV, p. 165.

Lateritic rocks of recent age.

In their geological age all these deposits belong to the recent period, having been formed since man's advent upon earth, as proved in many cases by their containing traces of man's handiwork, in the shape of chipped stone implements of palæolithic types. Wherever such implements were found, beds of shingle and gravel were also found, or traces of their having once existed there, or at no great distance.

Divided into five areas.

By far the greatest development of lateritic deposits and implementiferous gravels occurs in the southern part of our area. Out of five principal areas of lateritic rock, four lie south of the Gundlakamma river; the fifth lies nearly 50 miles further northward, and forms an appendage as it were to the south-eastern flank of the Kondavidu hill range.

These principal lateritic areas may be conveniently called after the chief places standing on or near to them, and beginning in the south, we find:—1, the Rámapatam (Ramiaputnum) area; 2, the Kandukur (Cundacoor) area; 3, the Devagudur (Davagoodoor) area; 4, the Ongole area; and 5, the Kopparu area. Besides these larger areas there are sundry small detached patches or outliers, and a considerable number of fringes surrounding the older rocks, especially the various patches of the Rájmahál rocks. The shapes of the larger areas as well as of the fringing patches are so varied and complicated that it would be useless to waste time in a hopeless attempt to describe what can only really be learnt by inspection of the map. A brief description of the petrological features of the principal areas and patches mapped and unmapped must suffice.

The Rámapatam area.

1. The *Rámapatam area* lies between the sea at Rámapatam and the alluvial valley of the Man-eru and its lower tributaries. A little to the north-west of the town the laterite approaches within a mile of the sea. It forms a low undulating plateau largely covered with thorny scrub jungle. The lateritic formations are generally very ferruginous, whether they be sands, gravels, or conglomerates. The gravelly form covers by far

the larger area, and is generally only 3 or 4 feet thick, and frequently pierced by rugged masses of the underlying gneiss. Only a few of the larger protrusions of gneiss could be shown on the map. The soil is almost everywhere of an intensely red colour, and where the water-supply is sufficient, of very considerable fertility. The lively contrast between the bright red soil and green jungle or fields gives this tract of country an eminently cheerful appearance.

In the south-western parts of the area, much of the lateritic gravel has been formed of washed-up purple sandstone and grit of Rájmahál age. Both rocks were highly ferruginous (hæmatitic), and in some fragments are to be found remains of the typical fossil plants. This is particularly the case between Rázpalem (Razpolliam), Chinna Látarapy, and Peddávaram (Peddawarrum), where the lateritic deposits often rest upon Rájmahál rocks. Near Rámapatam the laterite, which is there a typical conglomerate, shows an easterly dip of from 2° to 3°. It contains no foreign substances, but a few quartz fragments; but further west, between Potelur and Gudlur (Goodloor), it includes many angular quartz fragments, some of quartzite (broken pebbles) and a number of rather poorly made chipped implements and flakes, also of quartzite. Though generally thin, the lateritic beds here and there show considerable thickness; as at Allampuram, east of Chinna Látarapy, where from 12 to 15 feet of intensely ferruginous gravel is cut through by a well-section. The conglomeratic form was specially noted near Lutchmepuram in the south of the area, and near Virapalle (Veerapully) and Bhimavaram (Beemawaram) in the north. The most striking and typical development of massive laterite conglomerate in this region is to be seen in a low hill immediately east of the great northern road and 3 miles north-west of Rámapatam. It is more clayey and less ferruginous than much of the conglomerate seen elsewhere.

Chipped stone implements.

2. *The Kandukur area.*—The lateritic formations within this area are principally sands and gravels. Conglomerates are rare, the only really striking examples being

The Kandukur area.

the spreads which cap the low gneiss hills at and around Singáraya Konda, a noted temple just off the great north road a couple of miles north of the ford over the Man-eru.

The sandy forms of the lateritic formations are specially well seen to the west and north-west of Kandukur and around Pokur, 6 miles further north-west. The sands, especially near the latter place, are intensely red in colour and highly charged with minute pisolitic grains of impure red or brown hæmatitic clay, highly indurated and coated with an external glaze. Gravel and shingle beds, often of extreme coarseness, are very commonly met with, *e.g.*, near Malapalle (Malapally), west of Singáraya Konda, near Anantásagaram, west and north-west of Kandukur, at Kondasamudram (Condasamodrum), Sakávaram (Saeawarum), and Kálamalla (Calamulla), villages from 8 to 10 miles south-westward of Kandukur. At some of these places as Anantásagaram and Kondasamudram the shingle is partly conglomerated by a lateritic cement, but at the others, and especially at Malapalle, the shingle is quite loose. At Malapalle the shingle bed is very remarkable for its extent, which is between 3 and 4 square miles, and for its great coarseness. It consists mainly of rolled vein quartz, but contains also numerous large pebbles of gneiss and quartzite. The thickness of the bed may be estimated safely at from 20 to 30 feet. In many parts the name of boulders would be almost a better definition of the water-worn masses than the term shingle. The ferruginous element is entirely wanting here, and the prevalent colour is white.

Shingle bed at Malapalle, &c.

Much of the surface of the Kandukur area is covered by thick cotton soil. The westernmost extension of the lateritics up the valley of the Paleru shows mainly coarse shingle beds with little or no ferruginous matter.

3. *The Devagudur area.*—Here the deposits, which are almost entirely of gravel and shingle, are greatly obscured by cotton soil, and no sections worth mention were met with.

The Devagudur area.

The ferruginous element is almost entirely wanting throughout this area. The shingle beds are most exposed along the northern side of the area between Venkanapalem and Ilavarra (Yellavurra). On the south

side of the area, at Kattambadipalem (a hamlet not shown in the map), 3 miles west of Devagudur (Davagoodoor), the shingle bed appears to rest upon a bed of saline clay which in that case must be reckoned as of lateritic age, for it certainly does not belong to the Rájmahál series. The section is, however, obscure, and the grey clays may really be part of the river alluvium and the overlying shingle merely a washed-up bed.

The Ongole area.

4. *The Ongole area.*—The characteristic ferruginous element of typical lateritic beds re-appears again in this area, owing doubtless to the presence of rich magnetic iron beds in the adjoining gneiss rocks of the Konijedu, Parnametta, and Ongole hills. The western and northern half of the area is entirely covered with thick cotton soil, but the southern half is occupied by bright red soil resting on lateritic gravel of very ferruginous character containing chips and pebbles of quartzite.

The laterite in the western part of the area, where seen, is always gravelly in character; but the coarse shingle so common in the Devagudür and Kandakur areas is here found no more.

Kopparu area.

5. *The Kopparu area.*—Only the gravelly form of laterite is here seen in a few well-sections, the general surface of the country being thickly covered by cotton soil. The laterite, which rests upon Rájmahál beds, extends eastward under the alluvium as far as Ravipadu and doubtless beyond, but the alluvium, which is pure cotton soil, then becomes too thick to be pierced by the village wells, or rather the water level of the country is reached before the cotton soil is traversed.

Parlapalle patch.

Of the smaller areas, patches, or outliers of lateritic rock, and of the fringing beds, but little of special interest can be recorded. The few remarks required will be given while taking up the several patches seriatim in geographical sequence from south to north. The first in order is the Parlapalle (Parlapully) patch, lying south of the Vupput-eru and under the parallel of 15° north latitude. The rock here consists of mottled ferruginous clay, overlaid by kankarry clay and very red sandy soil, which becomes

covered with cotton soil on the higher ground to the south. Both this patch and the Rámapatam area are shown on the map as extending south beyond the limits of sheet 76; this is correct, but the extension is for a very short distance only, as the gneissic rocks appear rapidly with the rise of the ground.

Proceeding north to the valley of the Musi (Mooshee) river, the three small patches near Annakarlapudi (Unnakarlapoody), Maddalur (Muddaloor), and Chilikipad consist of coarse shingle, but are much obscured by cotton soil.

Amanabrolu patch.

The Amanabrolu (Ammanabroloo) laterite area, 9 miles north-eastward of Ongole, forms a low flat down, which is quite bare of vegetation opposite Sowtapalem. It consists generally of lateritic gravel, but a true conglomerate with included quartzite and gneiss pebbles, and numerous fragments of the Rájmahál rocks, occurs in the southern slopes. To the west and north everything gets soon covered up by thick cotton soil.

The fringing beds around the Rájmahál patches of Budaváda, Idupulapadu, and Pánur, and the small outlier at Parachur, on the old Madras-Guntúr road, all consist of lateritic gravel much mixed with and obscured by cotton soil. It is only here and there over small surfaces that the beds are conglomeratic and consolidated.

Guntúr laterite.

The laterite at Guntúr is partly gravelly, partly conglomeratic, the latter variety being best seen to the south-east of the town, close to the alluvial boundary. In the town the laterite rests on soft gritty sandstone of Rájmahál age, but to the west and north-west it overlaps on to the gneiss. The patch of gneiss which runs up from near Guntúr to the bank of the Kistna is fringed by gravelly laterite more or less all along its eastern side.

The two Rájmahál inliers in the alluvial spread adjoining the Kistna delta to the east of Guntúr both show extensive fringes of lateritic gravel. The northern or Tangellamudi inlier is fringed nearly all round. The southern or Chebrolu inlier is fringed similarly in its northern half and at its extreme southern point. The

intermediate part is very probably equally fringed with the lateritic gravel, but its whole surface is completely masked by thick cotton soil.

Palæolithic stone implements.

The occurrence of stone implements of palæolithic type in the laterite at Potelur in the Rámapatam area has already been mentioned (page 87). From the Kandukur area several very fine implements were obtained, to the east and west of Kandukur itself and from Kondasamudram. Others were found in the northernmost part of our area, in the fringing laterite at Ippatam, close to the Kistna. A much larger number, however, was obtained from some of the outlying unmapped shingle patches, the more important of which will now be enumerated. They are especially numerous in the valley of the Man-eru and its tributaries, where they occur at intervals all up the course of the river, at levels above the recent alluvium, *e.g.*, at Nàkanampetta, near Màregunta, around Velegunla (Valegunlah), at Sallawárpalle, and at Kambaldinna (Cumbaldinna), also at Kattakindápalle (Cuttakindapully), Mupád (Mopaud), Chintalpalem, and Kothápalle, all on the south bank of the river; nearly all these beds yielded implements.

Of the places on the north bank, two especially, Lingasamudram and Comarapallem (Bompeadopaud of map), yielded many good implements, though but little remained of the shingle beds they had been preserved in. Further west still, implements were found associated with the shingle beds near Irur (Eroor) and Iskapalle, and in the shingle bed which lies like a talus at the eastern foot of the Vaimpad quartzite hills south of Pámur. In parts these beds are so immensely coarse as quite to deserve the appellation of "boulder gravels." They are generally more or less ferruginous.

A remarkable shingle deposit, in which, however, no implements were found, occurs on the banks of the Chundi nullah, about 3½ miles east-by-north of Chundi village. The shingle, which is of gneissic origin, is far too extensively developed to be attributed to the formative power of the local stream. The ferruginous element is greatly wanting in this case.

Considerable spreads of coarse gravel and shingle, the ruins as it were of once existing beds, remain scattered over the gneiss to the north and west of Maddalur (Muddaloor), in the valley of the Musi-eru.

The most westerly point north of latitude 15° at which I found implements in this region is Ramiapalle (Ramiahpully), 23 miles north-west-by-north of Pámur, where considerable traces remain of a former extensive development of lateritic beds in the shape of lateritic gravels and dark red sandy clays.

The surface of this tract, and indeed of the whole area drained by the headwaters of the Pal-eru, is much covered and obscured by drifts of bright red blown sand, which will be again referred to further on.

The last shingle bed to be mentioned occurs far north of all the others at the village of Angulur Agranaram, 9 miles north of Vinukonda. Here a highly kankarry shingle of gneiss and quartzite contains many rude, and some good, palæolithic implements.

Resemblance of non-ferruginous shingles to Conjeveram gravels.

A strong petrological resemblance exists between many of the non-ferruginous shingles and gravels just described, and the equally non-ferruginous Conjeveram gravels of the Madras area,[1] but they (the northern beds) are not restricted to one particular tract, as are the southern ones, and there is no reason to look upon them as in any way distinct from the ferruginous beds, their mineral character only excepted.

CHAPTER VII.—THE ALLUVIAL DEPOSITS.

A very large area of alluvium lies within the limits of the tract described in this memoir, as it includes the major part of the delta of the great Kistna river. A minimum of time was available for the alluvial deposits, so the examination they underwent was necessarily quite cursory, but that was enough to give an idea of their general

[1] See Memoirs Geol. Surv. India, Vol. X, p. 41.

character. They must be grouped as of two great classes, marine and freshwater, the marine including the brackish water æstuarine formations.

Marine and æstuarine alluvia.

But few data have been collected to show how far inland from the present coast line marine alluvia exist. The most recent information on this subject was obtained during the extension of the Kommamur canal, which starts from the southern end of the Bezwada anicut to meet the East Coast canal now known as the Buckingham canal. The beds cut through in excavating this canal in the southern part of the Bapatla taluq were largely marine, as shown by numerous subfossil shells exposed. A small collection of these[1] shows the following species:—

Murex, sp.	*Turritella.*
Eburna, sp.	*Placuna placenta.*
Oliva, sp.	*Arca granosa.*
Voluta, sp.	*Cyprina*, sp.
Natica, sp.	*Cytherea castanea.*
Terebralia telescopium.	

These were obtained at Santaravur, in dark grey clay associated with considerable quantities of selenite crystals in large complicated macles, which were found a great source of discomfort to the coolies, by cutting their bare feet. The shells are mostly in excellent preservation.

Marine fossils found miles inland.

The furthest point inland at which marine beds are positively known to occur is at, Golabapilli in the Gudivada taluq, a place a little outside the northern limits of the map illustrating this Memoir, and lying at a distance of about 20 miles from the nearest point on the coast. Fossils were here obtained by Mr. Peters, C. E., D. P. W. Among them were a good-sized crab, a shell of the genus *Mactra* (?) and a branch of Nullipore. These fossils also were found in a bluish-grey clay; unfortunately no detailed information concerning them had been noted, and the section from which they were obtained had been filled up again.

[1] I am indebted for this collection, as well as for much courteous and kind assistance in other ways, to Major (now Lieut.-Colonel) Hasted, R.E., who was Superintending Engineer of the Kistna and Godávari ranges during the time I was surveying in that neighbourhood.

Subfossil shells from Masulipatam.

From the materials thrown up into a dyke near the light-house at Masulipatam, a considerable number of subfossil shells were collected by me. The following is an incomplete list of the genera obtained from the sandy clay:—

Pyrazus.	*Arca*, 3 sp.
Potamides.	*Cultellus.*
Nassa.	*Solen.*
Nerita.	*Tellina.*
Valvata.	*Mactra.*
Paludina.	*Pholas.*
Lymnæa.	*Ostrea*, 3 or 4 sp.

The swampy flats near the coast abound in shell-fish; those within tidal influence show brackish-water forms, as *Potamides,* and those further inland purely fresh-water forms, as *Paludina* and *Planorbis,* sometimes in enormous number.

The eastern part of the delta has a sandy surfaee; the western part is covered with dark black washed up regur (cotton soil). The boundary line between the two runs through Weeyoor in a north-easterly direction. My attention was drawn to this by Lieut.-Colonel Hasted, R.E., who also informed me that this boundary is distinctly marked for a long distance, the western edge of the sands forming a slightly elevated ridge across country. It would be very interesting to ascertain whether this disposition of the sands depends in any way on wind action, or can be connected with the great tidal waves which have at long intervals devastated the delta, as in the terrible cylcone of 1864, when the sea water rushed inland for a distance of over 15 miles.

Considerable changes have taken place in the form of the coast line within the memory of living men. There is a marked difference between the lines laid down by the surveyors from whose survey sheet 95 was compiled and the lines ascertained a few years since by the officers of the Madras Revenue Survey. As might be expected, the delta is advancing on the sea, and would do so much faster but for the very powerful coast currents which flow up or down according to whether

the south-west or north-east monsoon may be prevailing. The mouth of the Masulipatam river is now quite different from what is shown in Atlas-sheet 95, edition of 1828. A long spit has been formed which has thrown the bar much further to the north.

In the region round the mouth of the Gundlakamma river, traces of marine beds were noted at considerable distances inland at three places: to the east of Uppu Gundur; also at Vinnawaddaroydipalem, on the north bank of the river, where subfossil marine shells are found in a clay bed about 4 miles inland; and at Biramgunta, on the south side of the river, where similar subfossils occur at a distance of 3 miles from the sea. The sandy character of the sea board holds good generally down the coast as far south as Rámapatam.

Fresh water alluvia.

To turn to the fresh-water alluvia: they are all of river origin in this part of India, and represent largely the character of the soil prevalent in the several hydrological basins. Thus the alluvium of the Kistna, which flows through enormous tracts of cotton soil in the Deccan, consists mainly of washed-up regur. Gritty sand and sands are comparatively rare. The Gundlakamma alluvium is chiefly sandy, and the alluvia of the other small rivers to the south of it are variable, according to the diversified tracts they have drained.

Characters of alluvia of different rivers: of the Kistna.

Of the Gundlakamma.

The alluvial basin of the Gundlakamma is the most interesting of the smaller ones. The river has changed its course near its mouth, and flows mainly through the southern arm which flows past Gundiapalem, and was an unimportant branch when the trigonometrical survey was made. The northern or Pedda Devarampadu branch, then the main stream, is now nearly abandoned and fast silting up.

A singular mistake occurs in the old Atlas-sheet 76 in connection with the Gundlakamma valley, a couple of hills being shown close to the river, near the crossing of the road from Ongole to Ammanabrolu. These hills have no real existence; their site is a perfect flat, covered with reddish-sandy loam.

Further up the river the banks become cliffs, and continue so generally up to Venkateshwarapuram, where a reef of gneiss crosses the river. About half a mile east of the village of Velampalle (Valumpully), where the great north trunk road crosses the Gundlakamma, the gritty alluvial sand cliffs were found to contain human bones imbedded at very considerable depths below the present surface—depths so great as quite to preclude the idea that the bones might be connected with any recent, or quasi-recent, burial. The first bone found was a lower jaw imbedded in an undisturbed bed of loamy sand 18 or 20 feet below the present surface. This find set me looking for more, and I succeeded in finding others imbedded in equally undisturbed sands at depths from 16 to 18 feet below the present surface. The other bones consisted of a scapula, femur, tibia, fibula, humerus, ulna, radius, and a few doubtful fragments belonging to more than one, and probably to three individuals. The bones present a rather recent aspect, no infiltration of mineral matter having taken place. They owed their position in the alluvium doubtless to flood action at a period when the Gundlakamma was forming the great flat it now cuts deeply into, and flowed at a level of from 30 to 35 feet higher than at present, or was subject to floods of vastly greater magnitude than those now occurring. Thin beds of gritty silt are intercalated with the sandy loam both below and above the sites of the bones, and in them are numerous *Unios* and *Melanias* of the same species as now live in the river.

Human bones at great depth in alluvial cliffs.

The alluvium of the small rivers draining the country between the Kistna delta and the Gundlakamma consists mainly of washed-up cotton soil, though sand, sandy loam, and silty grits are occasionally met with. Gravels are rarely seen.

Alluvia of the smaller rivers and streams.

The streams draining the great cotton soil tract lying north and west of the Kondavidu hills form remarkably distinct and striking alluvial flats along their courses, and, as might be expected, these flats show hardly anything but washed-up cotton soil.

The river side cliffs frequently show beds of the dark reddish-brown clay underlying the top bed of washed up regur. This may be seen in

all the rivers. Unfortunately no organic remains were found in any of these lower clays.

Sandy alluvium of the Man-eru.

The alluvium of the Man-eru (Mun Air) is by far the most sandy of all the smaller rivers, a fact quite in keeping with the general character of the area drained by it, which show less regur than do the basins of the other rivers. Much of the red sand covering the flats near the junction of the Man-eru and its principal branch, the Vupput-eru, is washed-up lateritic sand, and so red in colour as to make it very difficult in many places to distinguish the boundary between it and the true lateritic sands. At Gundlapalem, as at various other places along the lower reaches of the river, the banks are high, and cut into small cliffs showing red-brown loamy sands 20 to 30 feet in thickness.

Shingle flats.

In the upper part of its valley the Man-eru cuts through two large flats of a very kankarry quartzite shingle, quite unlike the reddish loamy alluvium the river is now forming on a small scale in a few spots above local barriers of gneiss. These flats are mentioned here as the shingles might, from their situation, very easily be taken for old river alluvia, but the probability is they are really of lateritic age, and implements were found on the surface of the upper flat. These flats, which have already been referred to (page 91), are situated to the north and east of Pámur, at Chintalapalem, near Kothapalle and Mupad respectively.

The alluvium at the junction of the valleys of the Pal-eru and Musi-eru is largely sandy, but higher up the valleys of both rivers cotton soil predominates markedly.

CHAPTER VIII.—SOILS AND SUB-AËRIAL DEPOSITS.

Distribution of red and black soils.

Three classes of soils are met with in the Nellore-Kistna country—the black, red, and white; but of these only the two first are of any importance. The black soil, cotton soil, or regur, covers the largest surface, and predominates in the northern

and eastern parts of our areas; the red soil, or lál, prevails over the southern and western parts, but is also to be seen almost everywhere around the bases of hills, or where the ground is very broken. It is the direct product of decomposition of ferruginous rocks. Cotton soil, on the contrary, is an indirect product, as it contains a much larger admixture of organic matter. Its great development over such large areas may in all probability be attributed to the former existence of large and thick forests, and to the former prevalence of a moister climate than now exists.

Cotton soil an old humus.

The cotton soil was the humus formed in such forests. It overlies all the formations of these regions indiscriminately, but yet shows no signs of aqueous deposition except in the manifestly washed up beds in the alluvial basins. Much of the regur, however, which lies on the surface of the river and coast-alluvia was formed *in situ* as a humus; at least this appears to be the only explanation of its occurrence over such extensive surfaces in the absence of all traces of any transportation by water and deposition as a true sediment.

Sub-aërial deposits.

The sub-aërial deposits met with can all be referred to two classes, the results of chemical and of mechanical action,—the former including all the tufas (kankar, &c.), the latter represented by the blown sands.

Tufas.

The tufas, including all the numerous forms of kankar, are met with pretty well everywhere and in every formation as foreign bodies introduced as products of decomposition or by infiltration. The commonest form of kankar is the gravelly or nodular, which forms so large an ingredient at the base of nearly every cotton soil throughout the country, and which plays so large a part in so many of the less ferruginous gravels of lateritic ages as already pointed out. It is needless to specify any examples of a formation of such exceedingly wide distribution and common occurrence.

Varieties of kankar.

Infiltration kankar which fills the joint clefts, and all possible cracks and crannies in the older rocks, and which in innumerable cases cements

together loose materials of all ages and descriptions, forming conglomerates and breccias of all characters, is the next in importance, and probably also in point of quantity. Lastly come the massive tufas usually forming superficial deposits, which are occasionally of some little importance. These appear to be in many, if not in all, cases to be really only a fuller consolidation, or a completion of the process to the partial action of which the other two forms of tufa are due. Examples of this are also very common, but a few of the more striking examples deserve to have attention drawn to them. An extensive pavement-like spread of massive tufa occurs a couple of miles west-by-north of Pámur, under the bund of the Dupuguntla (Doopoogoontla) irrigation tank. Several small springs issue from below this mass, which rests upon gneiss. Another remarkable and extensive spread of tufa occurs at the Kalingula (waste weir) of the large tank at Kanigiri, and extends for a considerable distance westward under the red soil.

Massive kankar near Pámur.

At Kanigiri.

Another great pavement of kankar is to be seen at the north-eastern end of the Kotappa Konda, and another of the same character at Yallamanda, a mile or so to the north-east and 4 miles south of Narasaraopett. The surface of the tufa here shows a remarkable coralloid sculpturing unconnected with any internal structure, but due apparently to the action of rain.

Near Kotappa Konda.

There is a great development of hard sub-crystalline kankar tufa north of Naganla, and about 3½ miles north of Budavada. Here the junction of the gneiss and overlying Rájmahál beds is completely concealed by the thick bed of very large quasi-stalacmitic masses.

At Naganla.

The last example of massive tufa is perhaps the most remarkable of all. It occurs along the brow of the high ground south of the Paleru valley, 3 miles northward of Kandukur. It is best seen at Konda-kandukur, where it forms sheets as it were in the bed of the large tank.

At Kovur.

The sheets of this tufa, which is very hard, close-grained, and of yellowish-white colour, show a lenticularly concretionary structure, which gives rise to holes and depressions in the surface; no trace of any organism could be found in it. At Kovur (Covoor), 2 miles to the west, it is seen to rest upon shales of Rájmahál age, but the section is too poor to show the real relation of the beds. It is the densest and most massive tufa I am acquainted with, and but for its concretionary structure, I should regard it as a sedimentary limestone, in which case it would doubtless belong to the Rájmahál series.

Blown Sands.

Blown Sands.

These Æolian accumulations are more commonly developed in the southern part of our area than in any other equally large district that I am acquainted with. But though so commonly met with, they are mostly of very moderate dimensions, and, except in a few cases, of no particular interest. Three sets of blown sands may be recognized: *1stly*, the coast dunes and flats; *2ndly*, the river-side dunes; and *3rdly*, the inland dunes unconnected with any river beds.

Coast dunes.

Of the coast dunes but very little need be said; those lying between Rámapatam and the southernmost part of the Kistna Collectorate attain to no height, though the spreads of loose sand are often more than a mile across. Of those in the Kistna district only a very small part in the extreme south, at Pedda and Chinna Ganjam, and those immediately to the north-east of Masulipatam, were visited. The remainder were for the present left untouched, but they had already been mapped by the officers of the Madras Revenue Survey, whose representation of them has been adopted and shown in the map accompanying this Memoir. It was considered unnecessary to devote to geological features of such very minor importance the considerable period of time that would have been requisite to travel over such a difficult country as the sandy and swampy sea edge of the delta of the Kistna. The sand hills at Chinna Ganjam and near

Masulipatam attain in parts a height of from 30 to nearly 50 feet, and where overgrown with pandanus bushes, cashew-nut trees, and other sand-loving plants, give rise to picturesque peeps one would hardly expect among sand dunes. A belt of Palmyra palms (*Borassus flabelliformis*) accompanies the coast sands with hardly a break. The moving of the sands can easily be checked by planting casuarinas, or the trees named above.

River-side dunes.

Small sand-hills are often to be seen at the bends of the different smaller rivers, where long reaches of sand, dry during the greater part of the year, are exposed to the strong land winds. Several of the larger are shown on the map, but many were seen too small to be mapped. Some of these river-side dunes are troublesome, as the sand advances from them over the fields and covers them injuriously. No attempts appear to be made to plant these small dunes to fix the sand. The self-sown Ipomea (bindweed) and wild grass are practically insufficient to stay the advance.

Inland dunes of red sand.

The inland dunes are a feature which is rarely seen in other parts of the country. Those to be seen in this region are found in the upper part of the Pal-eru valley, east and south-east of Nandananam (Nundanawonum). That they are not river-side dunes is clear from their positions, and from the fact that the sand in the river beds is drab or greyish, while the sand hills are bright red, almost scarlet when seen at a little distance in strong sunlight. The best-defined and most striking is that of Narrava Gopalpur, at the northern extremity of the Kodni Konda ridge.

Narrava Gopalpur sand-hills.

This sandhill is 4½ miles long, and generally about a quarter of a mile wide. The sand contains a proportion of clay sufficient in parts to make the whole bind into a tolerably compact mass,—not so compact, though, but that it crumbles down under one's feet. Another well-defined red dune occurs at Kondareddipalle (Condareddypully), about 5 miles to the north-east. Several other accumulations, of equally red colour, occur to the west of Hanumantapad and near Chinna Gollapalle, and others also to the west of the Kodni Konda, near Nandananam, Ramapalle, and Pondhova. To

the east of Hanumantapad are two or three vividly red hillocks piled up against the side of pale quartzite hills, and making a striking contrast of colours.

Nandananam valley.

As seen from the top of the quartzite ridge west of Kondareddipalle, the whole of the great flat valley of Nandananam in the corner between the Kodni Konda and the bend of the Vellakonda range, is seen to be covered by soil of the most intense red colour—the reddest tract of country I can recall to mind. The derivation of the red ingredient is a problem to be solved; the great richness in iron of the local soil does not agree with the character of the surrounding older rocks so far as they are seen. Both the mica schists of the gneissic series and the quartzites and slate of the Kadapa rocks are locally very poor in iron. This suggests that the ferruginous material came from elsewhere, and I believe it will be found that there was once a large development of lateritic beds in this old bay, remnants of which remain in the lateritic gravels exposed here and there under the sandy red soil of Nandananam at Ramapalle and Pondhovah, the red sands themselves being detritus of parts of the formerly more extensive beds. This redness of the soil is confined to the basin of the Pal-eru, and is not seen on, or north of, the water-shed between it and the Musi-eru.

Iskapilly sand-drift.

A solitary patch of similar bright red sand occurs piled against the side of the Iskapilly hill, 30 miles to the south. These red dunes are due to the action of the local winds (generally strongest from the south-west), tearing up the surface of the red soil during the dry weather. On a very small scale they resemble the "terais" of Tinnevelly district, but are brighter in colour, and contain a larger admixture of clayey particles.

CHAPTER IX.—ECONOMIC GEOLOGY.

The circumstances of the case unfortunately compel the admission that the mineral resources of the area described in the foregoing pages are very small as regards all the really valuable and important minerals. It is only in the matter of building and road materials that the country is well off; and even in this matter it is no better off than the average districts further to the south. Of metallic ores, there is certainly an abundance of good iron; but as unfortunately no coal or other mineral fuel accompanies it, it must for the present remain unused and uncared for. Whether this state of things will remain so or not remains to be seen. The opening of the new east coast, or Buckingham Canal, may possibly render the magnetic iron of the Ongole beds valuable enough to be carried to Madras, or to some other point where sea-borne coal might be used to smelt it. Canal carriage being extremely cheap as compared with all other methods, it may be worth the while of those interested in the matter to look into it. The Napier Iron Foundry in Madras is said to use indigenous iron ore from Nellore district, but there is no magnetic iron in the southern part of the district, so they are probably using a lateritic ore greatly inferior in wealth and quality of iron. Should the Ongole iron beds be made available to supply ore, it might lead, later on, to the working of some of the other beds that are close to the Gundlakamma or the Man-eru rivers, as they could be placed in direct communication with the canal for a few days in the rainy seasons. No iron smelting industry seems to be followed by the natives at present in the parts described in this Memoir, though it formerly existed, and is mentioned by Dr. Heyne.

Influence of the new canal on a possible iron industry.

The only other metallic ore met with was copper, but merely in very minute traces, as malachite, or green carbonate, occurring in tiny cavities, and those very scarce indeed. This was found at the northern end of the Gogulapalle quartzite ridge (see page 13). The indications were not at all promising

Copper ores.

of the discovery of the further occurrence of the ore in any really valuable quantity; and the past experience of copper-mining in Nellore district is so extremely unfavourable, that it is hard to anticipate that any valuable lode or pocket is likely to be found. Several natives were said to be prospecting in that neighbourhood at the time of my visit (in 1875). I fear they would be most grievously disappointed.

Garnet sand and staurolite substitutes for emery.

Garnet sand is collected by the natives and sold in the bazaars as a substitute for emery, but they seem unacquainted with the fact that staurolite, of which an immense quantity is to be had in and near the Chundi hills for the mere trouble of picking it up, is a material of superior hardness to common garnet. Even in the European markets the value of staurolite in that respect appears to be unknown, probably because hitherto untried.

Lime.

The supply of lime is abundant, most of it being obtained from burnt kankar, except on the coast, where recent and sub-fossil shells are collected: the natives do not appear to have had recourse as yet to any of the crystalline limestones.

Selenite gypsum.

The selenite occurring in the marine beds along the new canal might be worth collecting, as there is an increasing demand for plaster-of-paris in Madras, and the specimens of it sent me by Lieutenant-Colonel Hasted, R.E., are certainly far larger and purer than those dug from corresponding marine clays in the neighbourhood of Madras.

Building stones.

The architectural inclinations of the Telugu people being very small as compared with those of the Tamil people, there are very few fine buildings of any kind by which to judge of the beauty or adaptability of the various rock varieties for building or decorative purposes. Most of the stone buildings to be seen are coarse and rude in their construction: this remark applies emphatically to nearly every modern structure. Good carving and elegance of design is to be seen in the few remains of Jain or Buddhist architecture to be

Native carving at Amravati.

found here and there. Foremost among these are a few carved slabs derived from the old Buddhist "Tope" at Amravati. The materials these slabs are carved out of is Palnád limestone, a sub-crystalline or crystalline rock of the age of the Karnul limestones, and therefore strictly speaking not belonging to this area.

Kondavidu.

Carved fragments of the red Tangelamudi sandstone, derived from some Jain temple, are to be seen in Kondavidu Drug, built into the walls of the north-eastern gate, and contrasting strongly with the remainder of the gneiss-built walls. The sandstone, some pieces of which bear inscriptions, has worn well, and shows but little weather action.

Aminbodu.

Two gems of carved and polished stonework are to be seen at Aminbodu, north of Kondavidu, and 10 miles west of Guntúr. Both are small temples of Jain origin; the northern of the two has once upon a time been converted into a Mussulman building by the construction of mauresque arches of rough stone between the round and highly polished stone pillars. The other is a low Hindu temple standing imposingly on a bold mass of granite gneiss. The southern doorway is surmounted by a very elegantly carved portico, while to the east another very elegant portico shelters a recessed shrine beautifully cut out of dark green stone, a true diorite apparently, to which a very high polish has been given. The pillars in the smaller temple appear to be of the same stone, and are equally meritorious specimens of stone-cutting and polishing.

Stone cart-wheel industry.

The only special branch of industry connected with stone that is now pursued in the Nellore-Kistna country, is the manufacture of stone wheels for agricultural carts of different sorts and shapes. This industry is followed at several villages near the boundary of the schistose area, east of the Podile hill.

The stone used for this, to European ideas so singular form of industry, is all quarried in the Kuchupudi (Koochoopoody) hill, or Andrakonda, a bold precipitous mass of granite gneiss, 800 to 900 feet high, lying 3

miles east of the south end of the Podile mountain. The rock is a grey or pinkish-grey homogeneously bedded form of granite gneiss, the felspathic ingredient predominating a little over the quartz, and both very much over the mica.

The masses to be converted into wheels are broken out with wedges in rude squares, which are first dressed into octagons or hexagons, these are then raised and set on end, and kept up while worked till complete. The wheels are generally perfect discs, in the plane of bedding, all but the box, which is kept nearly three times as thick as the peripheral parts. In a few cases I have elsewhere seen lensiform wheels. The hole for the axle is drilled from both sides, till a thin diaphragm only remains, which is then carefully broken out. Occasionally the sides of the wheels are ornamented with elegant scroll patterns.

The cost of the wheels increases very largely in proportion to their size, which is measured in spans and finger-breadths from the centre to the circumference. A pair of wheels of three spans and four finger-breadths semi-diameter will cost 8 rupees, a pair of four spans semi-diameter 10 rupees, and a pair of five spans semi-diameter not less than 20, owing to the increased difficulty of getting the large-sized blocks. A large pair of wheels is two months' work for one stone-cutter. These wheels are said to be very durable, unless exposed to sudden collision with rocks, and their durability is said to improve with time: a pair of large wheels equal to a burden of one candy in the first year, will bear two candies in the second.

The Kuchupudi quarries occupy 30 stone-cutters, and turn out about 100 pair of wheels in the year, and neighbouring villages supply a smaller number, in addition to gneiss troughs, curry-stones, &c.

The stone-wheel industry exists also, according to the Kuchupudi people, at Dekerekonda near Darisi, where a similar but rather paler granite gneiss is worked. I had no opportunity of examining this latter quarry.

But little use is or has been made, except as rough building-stone, of the many very handsome varieties of granite gneiss that might be quarried at very many places in the granitoid areas, Kondavidu especially. The

largest rough stone buildings of olden times are the old hill forts of Kondavidu and Bellamkonda; of modern buildings the great anicut, or weir, over the Kistna is pre-eminent.

The Rájmahál sandstones of Tangellamudi, Chebrolu, and Pávulur supply the Public Works Department with considerable quantities of building material for the various works—bridges and sluices—connected with the irrigation channels in the western delta. The two former localities were also largely resorted to at earlier times for their red and purple sandstones, which, from their easy workability and rich colour, were in great demand for temples and for gravestones by various castes of Hindus.

The new field demarcation accompanying the revenue settlement has also created a local demand for rough boundary stones in many places where they were not previously quarried, and in many of the alluvial tracts such stones have been carted a long way.

Some fine examples of old carved and polished stones, which must have been carried long distances, are the carved bulls and lingams remaining among the ruins of several temples at Kanupati, on the coast, a little north of the mouth of the Gundlakamma. These ruins do not stand, as stated in the Nellore District Manual (page 431), upon a reef of hard rocks, but upon the pure alluvium, in which not a scrap of stone is to be traced except the ruins of the temples themselves.

Large quantities of salt are made at numerous salt-pan stations along the coast, but they offer no peculiarity requiring to be mentioned here.

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MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA.

THE GNEISS AND TRANSITION ROCKS, AND OTHER FORMATIONS OF THE NELLORE PORTION OF THE CARNATIC, *by* WILLIAM KING, B.A., *Deputy Superintendent (Madras), Geological Survey of India.*

PART I.

CHAPTER I.—GENERAL DESCRIPTION.

The selection of a fitting title for this memoir has been beset with much difficulty, for the country, the geology of which is about to be described, is not defined by any political or natural boundaries, except on two sides, while it includes portions of three districts in the Madras Presidency; neither is there any special formation or series typically displayed in the area, sufficiently so at least to be thoroughly worthy of separate treatment. Still, as the most prevalent and conspicuous rocks are of the crystalline series, and the relations between this and the transition series are more frequently displayed within this part of the Nellore District than in any other portion of the Carnatic, these formations are selected as the more particular theme of this work. The *modus operandi* of the Geological Survey is likewise largely accountable for the presentation of such an undefined area, for at the time when it was examined, the grouping of the various rock systems of India was still in abeyance, and the areas for survey were chosen partly according to the sheets of the Indian Atlas. It is in this way that other portions of the Carnatic have been already

Introductory.

reported on, such as the Madras and Kistna regions,[1] which tie on to the northern and southern edges of the present area.

The examination of this ground was originally taken up by the late Mr. Charles Æ. Oldham and myself in 1861 while following out the transition rocks of the Cuddapah district; but the publication of the geology of more important areas, and the death of our colleague, who would most likely have written this memoir, have delayed the description of this country until now. Dr. Oldham deferred any memoir until there might be an opportunity of revisiting that portion of the district in which the complicated and obscure relations of the Cuddapah rocks and the gneiss are displayed, but as there has been no chance of this with the reduced number of the survey party in this presidency, and this condition being likely to continue, I have been requested to prepare this treatise from the observations and notes then recorded.

Area of country defined.

The country so introduced to the reader is a compact more or less rectangular strip of the Carnatic, lying between about the 13° 20′ and 14° 59′ parallels of north latitude, with the Bay of Bengal on its eastern side and that portion of the Eastern Ghâts called the Veligondas[2] as its western edge: it includes rather more than the southern half of the Nellore district and portions of the northern edges of those of Madras and North Arcot.

Towns and communications.

There is only one large town of importance, namely, the zillah station of Nellore, but two other smaller and purely native towns, residences of the Chiefs or great zemindars Venkatagiri and Kálahásti (Calastry), mark respectively the western and south-western parts of the field. It is traversed by two important rivers, the Pennér and Swarnamukhi, the proper basins of which lie, however, to the westward of the Eastern Ghâts. Communication is effected by the great northern trunk road, and this is connected at Nellore and Gúdúr with the western districts of Cuddapah and North Arcot by two less important roads crossing the Eastern Ghâts at the

[1] Mem. Geol. Surv. of India, Vols. X and XVI, pt. 1.

[2] Also Vellacondas, Yellacondas, and Vellicondas.

Doranál and Rápúr passes, and by a third along the valley of the Swarnamukhi. A great canal connecting Madras with Cocanada, a distance of nearly 400 miles, traverses the country by a system of salt and fresh water lagoons extending from the Pulicat lake nearly parallel to the coast. The sea-board, though quite unsheltered, and dangerous at its southern end, where it is marked by a small light-house opposite the great Armogamor shoal, offers anchorage to occasional vessels at Ramiapatam and Kristnapatnam at the proper seasons.

Climate.

The climate is a hot and dry one for most parts of the year, the effects of the south-west monsoon being only felt slightly on this side of the Peninsula, while the north-east rains do not generally last more than a month in any force, though the wind blows strongly for a longer time. During the former monsoon the two main rivers are down in flood, especially the Pennér, whose waters are, however, retarded by a dam or anicut near Nellore; and thus indirectly, and in the one case artificially, a part of the country is enabled to derive great benefit from the rains falling far to the westward. At this season also, it often chances that the sand banks barring many of the sea-outlets of the smaller rivers are eroded, when a refresher is given to wastes of water which are too often liable to become stagnant.

Fertility.

With such a climate and because the soils are generally poor, the country is not naturally a very fertile one, the wilder parts in the neighbourhood of the western hill-ranges being covered merely with low tree and scrub jungle, while the cleared ground, except near the numerous artificial tanks or alongside the rivers, is only favourable to dry grain crops, and those not very rich ones. The soil is often largely impregnated with soda, and the waters of most of the streams, the Pennér excepted, are also much charged with this mineral, for which reason much of the alluvial deposits bordering the coasts are very poor. The soils of the Pennér valley and delta are, on the other hand, formed of deposits brought down from distant fields of rock and cotton-soil, giving much more fertile sediment. The fringe of

cocoanut and palmyra palms, so characteristic of the Coromandel, is here much diminished in breadth and luxuriance, becoming very narrow and poor at the northern end of the area,—a feature which is perhaps attributable to some extent to the diminishing width of the sandy deposits of the coast. At all events, the palmyra is in much greater force towards the Pulicat lake, where also the belt of sand-hills is widest.

The people.

The people are principally Teloogoos, in fact the southern edge of the area may be roughly considered as the boundary between the Teloogoo and Tamil-speaking races. There is also a remnant of an aboriginal race, sometimes called Yanádis, dwelling in and about the island of Sriharikota, where there is a good deal of waste jungle-land. Indeed, it is a strange feature of this part of the Carnatic that one may here meet, within such close proximity to Madras, a tribe of people which still retains some of the manners and customs of a very primitive section of the human race, to such an extent that an iron arrow-head is treasured by them as a rare thing, the points of their wooden arrows are hardened by charring, and they are in the habit of obtaining fire by friction of wood, although fire is procurable at villages close by.

Mineral resources.

Mineral resources are few and far between, but some of these, such as the copper ores, have not as yet undergone all the investigation that their indications entitle them to. Building-stone from the gneiss is often conveniently situated and of first-rate quality, but that most easily and cheaply worked is the laterite, which came in well for the trunk road, and again in the irrigation works on the Pennér near Nellore. Some crystalline limestone occurs associated with micaceous and quartzose schists, but it is not suitable for the manufacture of lime, the common kankar or calcareous travertine being the general source for mortar. There is, however, a special store of this material in the seams of sub-fossil shells to be found a short distance inland from the coast back-waters and at a small depth from the surface.

The frequent occurrence of the products of felspathic decomposition offers sources for the extraction of salt, soda, and saltpetre, and for the manufacture of bangle glass; but these operations are really only spasmodic, natives, as a rule, seldom manufacturing more than is sufficient for local use. The extraction of salt from the lagoon waters is, on the other hand, an extensive and profitable industry, and this is nearly altogether in the hands of Government. There are good indications of fairly rich copper ores on the northern edge of the field, but in spite of many costly attempts which have been made within the last fifty years to work them, the results have hitherto been ruinous.

Iron has never been extensively smelted, only a few furnaces being worked at all regularly, though there is a strong run of iron beds in the southern part of the field. Diamonds are said to have been found, but reliable information could never be obtained on this point, neither were any traces of old workings ever met with. There is, however, a *primâ facie* expectation that those gems should be found near the mouth of the Pennér gorge, this being the only funnel through which any debris of the diamond-bearing deposits could be carried from the Cuddapah or Kurnool district, where diamonds are worked,[1] or were formerly found at no great distance up the river. The conclusion is, that if few stones are or were obtained so much higher up the rivers, then fewer, or none at all, could be expected to occur below the gorge. However, there are old diamond workings in the Kistna district, in the north-east prolongation of the Eastern Ghâts, which appear to have been in true Cuddapah strata, and not merely in beds of the newer Kurnool rocks, as is more generally the case; and as the Veligondas are of Cuddapah beds, it may after all be that diamonds have been found to the seaward of these mountains. Other minerals, sometimes of use to the jeweller or lapidary, such as garnets, rock crystal, amethyst, and the pretty blue kyanite, are not unfrequent, but these are never good enough to be of any particular value. Mica is sometimes obtainable in moderately-sized plates large enough to be used for small wall-lights and other decorative purposes.

[1] See Mem. Geol. Surv. of India, Vol. VIII.

Previous literature.

The previous literature touching on any geological points of interest in this part of the Carnatic is very slight, and indeed this is only what might be expected, there being little to attract the attention of the mere amateur or official traveller whose bent may be scientific. That once indefatigable explorer, Captain Newbold, has, however, left the traces of his footsteps here as elsewhere over Southern India in notes of a traverse across the Veligondas, and of an examination of the site of the old copper mines of the Nellore district; but these are very short, and do not enter into much detail. Dr. Benjamin Heyne (1800) also refers to the copper mines in his Tracts on India, but not at any length, at least as regards the old mines of this area. In 1836, Mr. James Prinsep, the then Assay Master of the Calcutta Mint, examined specimens of the Nellore copper ores, and a report of his results is given in the Madras Journal of Literature and Science.[1] In that year also, Colonel Mentieth, of the Madras Engineers, published an account of his trip to the Kambák Droog,[2] but there is nothing strictly geological in this paper. A further visit (1839) was made by Captain J. A. Smith to the same range, but more for the purpose of ascertaining its height, there being at that time an enquiry as to the availability of this little hill-range as a sanitarium for Madras.[3] In 1857 the question of the existence of coal, which used to trouble Madras for many years, was revived by Mr. G. Powell, Assistant Engineer, who reported on the appearance of coal at Nellore.[4] The mineral so brought to notice was *schorl;* and since then up to within the last few years, schorl has done duty for coal several times, not only here, but also in the Kistna and Godávari districts. Mr. J. A. C. Boswell's exhaustive Manual of the Nellore district appeared in 1873, and it completes the history of the literature so far. The geological chapter in it was supplied in part by Charles Æ. Oldham, and in the mineralogical chapter there is a full history of the copper workings, as well as much information on the little iron ore obtained in the district.

[1] Vol. III, Old Series, p. 154.
[2] Madras Journ. Lit. and Sci., Vol. IV, O. S., p. 134.
[3] Madras Journ. Lit. and Sci., Vol. IX, O. S., p. 311.
[4] Madras Journ. Lit. and Sci., Vol. XVIII, O. S., p. 291.

Work of survey.

The geological survey, as already stated, was conducted for the most part by the late Charles Æ. Oldham, then Deputy Superintendent, and by the writer, but certain parts of the country were revisited in later years by Mr. R. Bruce Foote mainly in connection with his examination of the extension of the Rajmahal plant shales.

CHAPTER II.—PHYSICAL GEOLOGY.

Table of rock formations.

The form of the country, within the limits laid down, is very simple, being a wide uneven plain, having the sea along one of its edges and a mountain wall on the other; but it is so intimately connected in its origin with the physical structure of the adjacent country, that important questions regarding the southern portion of peninsular India may to a certain extent be touched on in describing it, and for the readier comprehension of this treatment of the physical history, the following list of the geological formations or groups is now given, even though there must necessarily be some repetition in the more detailed discussion of them in their proper chapter :—

LOCAL GROUPS.	INDIAN EQUIVALENTS.	EUROPEAN EQUIVALENTS.
g. Blown sands. ...	......	*Recent* and *sub-recent.*
f. Alluvial deposits (River and Backwater).	......	
e. Lateritic conglomerates and *breccias, Gravels, Talus debris.*	*Lateritic deposits* (R. B. Foote).	POST-TERTIARY.
d. Laterite and *Ferruginous sandstones.*	*Cuddalore sandstones.* ...	*? Middle Eocene.*
c. Plant shales. ...	*Rajmahal beds.* ...	JURASSIC.
b. Quartzites and *Clay-slates.*	CUDDAPAH SERIES. ...	? LOWER PALÆOZOIC.
a. Gneisses of various kinds. *Granites* and *traps* associated with (*a*) and (*b*).	GNEISS.	

Marked features of low country and ghât step.

The southern portion of the Peninsula is distinguished by a great and well-known physical feature, namely, the arrangement of the land surface as a coastal plain or the low country, with a more or less distinct step or ghât edging an

upland; and these are well marked in the present area by the wide belt of plains and the western barrier of the Veligonda mountains, which are at the same time geologically distinct, the former being of gneiss, covered up in a scattered way (more perfectly towards the coast) by later formations, while the western hill wall is of the hardest rocks of the Transition or Cuddapah series. The plains are, however, much diversified by low hills and ridges in their middle portion, and by outliers of the mountain wall and other lower ranges lying to the south-east, they themselves having at the same time an easy slope up to the base, or rather up to a great talus of debris collected at the base of the western hills. The low country proper seldom rises more than 150 feet above the sea, but the talus, which is often more than 4 miles in width, sometimes attains a height of 250 feet. The Veligondas have an average height of about 2,000 feet, the peaks of Penchalakonda and Nagwaram being at least over 2,500 feet. The immediate outlier of Udayagiri is said to be 3,030 feet high, and the larger one of Kambák Droog, on the southern edge of the field, is about 1,800 feet. The Veligondas present a generally steep face to the sea, but this is very much scored by deep valleys and ravines, and is even cut right through by the Pennér river at the Somisilla gorge. There are some very fine cliffy headlands, especially to the north of this gorge, and the southern outlying Kambák Droog and the smaller Kálahásti range are even more precipitous. To the north of the Pennér the Durgama Konda outlier differs from the rest in having a long sloping back to the seaward, while its much steeper face is to the westward; and Udayagiri Droog is a conspicuous plateau with lofty and nearly perpendicular edges.

How formed.

The carving out of the great plain and step of mountain wall was evidently in the greatest measure the work of marine denudation, though subsequent atmospheric and river degradation, following on possibly more than one elevation above the sea, and later levellings up by the deposition of newer formations, have almost entirely obliterated all trace of this. The marked distinction between plain and wall is at the same time in part due to the

very different constitution and durability of the rocks composing each, while erosion must have been considerably facilitated by a system of faults occurring along the boundary; and had it not been for the very unassailable constitution of the Velingonda rocks, it is quite possible that this part of the Carnatic might have been nearly as broad as it is in the Madras and North Arcot districts, over which the transition series does not appear to have ever extended much further than the Naggery and Narnaveram hills. As it is, the belt of hard strata withstood the slow wearing of the sea, and it now remains as perhaps the most clearly marked and abrupt step between the lowland and upland on the eastern side of the Peninsula.

Approximate age of.

The process of carving out having gone on in both the transition rocks of the step and the gneiss of the plains, it must have taken place after the period of the former and before the deposition of any later series on the plain below the ghâts. The only evidence bearing on the latter point in this area is, that the Jurassic plant shales far out on the plains and near the coast show beds containing what I take to be pebbles of transition or Cuddapah quartzites. The upper Gondwána beds do, however, lie on the gneiss and close up under the Kambák Droog outlier of the ghâts in the Madras district: hence the step and plain must have been in existence at the latest in early mesozoic times.

Minor orographic features.

As regards minor orographic features, the northern half of the country is marked by many ridges and some *roche-moutonnée*-like masses of small elevation, such as the Narasimhakonda ridge to the west of Nellore and the Buchireddipalem hill north of the Pennér, the southern half having only low and broad hill masses. The ridges which are the most characteristic of the smaller elevations are attributable to the greater frequency of bands of crystalline quartzites among the gneiss series of the middle ground, the intervening softer schistose strata having been worn down to the lower general level of the plains; and the more rounded and less conspicuous detached hills owe their form to some large masses of trap associated with hornblendic rocks.

A much less conspicuous elevation as compared with those described, but still remarkable and worthy of attention as being continued with tolerable distinctness along nearly the whole of the Coromandel, is a narrow and very low plateau ridge of sandstones, with a lateritic covering running generally north and south at from 10 to 20 miles inland from the sea shore, and which corresponds with or is an extension of the Red Hills of Madras, Pondicherry, Cuddalore, and Samulcottah, in the Godávari district. Here, however, it is perhaps better defined than in any other equal length of the coast line, while it preserves a tolerably uniform level surface seldom varying much between 40 and 70 feet above the sea on its higher or western side. The edges are well defined, particularly on the western side, by a slight steep slope, or else a low scarp, and sometimes even by fair headlands giving a clear look-out over the intervening low country towards the mountain wall, whereas the eastern side is distinguished by the flat alluvial deposits shoring up along the very gentle seaward slope.

The low plateaus of the coast.

This plateau ridge marks what may be considered the last permanent upheaval of the Coromandel; but the views of the Survey differ as to the period when this may have taken place. Mr. Foote is inclined to consider that it took place during the human period, since he has found stone implements of human manufacture which he considers were embedded in the laterite capping the southern portion of this ridge in the Madras district, having been dropped by their owners in the waters then covering the country. I too found the same kinds of implements embedded in a lateritoid deposit, but it certainly appeared to me then, and still does so, safer to look on these as having been cemented with other debris by ferruginous waters under ordinary atmospheric exposure, and that these weapons were dropped on dry land or in fresh waters, that land being possibly more covered with jungle and water much after the style of the southern coast of Ceylon, where an analogous rock to laterite, locally called "cabook," is still being formed. The sandstones of this ridge being of presumably early tertiary age, the last elevation of the Carnatic must be of later times, but I think it is yet doubtful whether we can fix it so late as the human period.

Age of.

The remaining lower and newest ridge of all is that of the sand-dunes on the seashore, which is entirely subaërial and consequently of ever-varying height according to the force of the winds. This belt is scarcely noticeable to the north of the Pennér delta, while it only obtains any marked width between the outlet of the Gúdúr river (Kandléru) at Kristnapatnam and the Pulicat Lake, on the northern shore of which some of the dunes are 30 to 40 feet in height.

Shore line of sandhills.

Between this and the chain of sandstone plateaus lies the comparatively level belt of fluviatile æstuarine alluvium, a good part of which is really at a lower level than the sea. Flooding is prevented by the banks of shore sands and dunes, and by the raised banks of the rivers, though there are still extensive flooded portions in the numerous large back-waters and lagoons,[1] of which the Pulicat Lake is the most striking example.

Intermediate alluvial flat.

Most of the lagoons, and especially the Pulicat Lake, are being gradually silted up, while others to the north of the Pennér delta are evidently very much smaller now than they used to be, the deposits from the smaller rivers being of steady accumulation and the blown-sands lending their feeble assistance. Fitful or permanent communication with the sea necessarily delays the silting up for a time, but the levelling up of hollows lower than the sea is just as certain a process as the denudation of land that once rises above it.

Beds and banks of sub-fossilized marine and æstuarine shells occur at shallow depths in this alluvial flat, but not at any decided elevation over sea-level, and these point to a further slight elevation of the country, though it is quite possible that they may have been brought up with the elevation of the Nellore plateaus.

The drainage system is very simple, there being only two large rivers, neither of which, however, rises in this field, and as this is not very wide, only some 57 miles, the rivers

Drainage system.

[1] There are also a few fresh-water lakes, which, however, may possibly have been reduced in number by the recent extension of the coast canal; but at the time of my survey in 1869 the long stretches of water at Kápúr and Pogaradinna were quite fresh, and the villagers stated that such had been the case for many years.

actually belonging to the area are not of much importance. The Pennér receives only the waters of a few small streams, prior to which it comes suddenly on the field with a nearly completed course through the clean-cut pass[1] in the Veligondas, thence flowing nearly due east to the sea in the shortest line it could take past Nellore.

The Swarnamukhi, though much smaller, is still a large river as compared with others in the district, and it brings down a large volume of water, many of its best feeders being in the neighbourhood of the Chittúr hills. It is also from this side of the country that some of the best affluents of the Pennér fetch its waters. The Swarnamukhi follows a much more irregular course to the sea, and does not show that decided general easterly trend as it approaches the coast, which is a marked feature in the Pennér and the other large rivers of Southern India. It also enters the country by a wide open valley, and only meets its later alluvial banks at a few miles from the sea. The other stream worthy of note is the Kandléru, the larger affluent of which rises in the Veligondas behind the Venkatagiri and Rápúr country and meets it in the alluvial flat of coastal deposits near Gúdúr, whence it flows to, and enters the sea by, the large back-water at Kristapatnam. To the north of the Pennér, there are only two small rivers flowing direct to the sea, which at flood times break the sand barrier to the eastward of Allur at Thulipallem, and again near Juviladinne.

The passage of the Pennér at the ghâts.

The noticeable feature in the course of the Pennér is that it passes right through or across the western mountain wall,[2] having worn its way downwards into the transition rocks covering the greater part of the Cuddapah district to the

[1] So suddenly and with such a gathering do the waters of this large river rise at the gorge, that the flood waters have occasionally been reported as reaching the anicut at Nellore before the runners can signal that preparation should be made at Nellore to meet the flood.

[2] It is as well to notice the mistaken, though oft-repeated, view that this and other great rivers, such as the Godávari, further north, have absolutely cut through what are now, in point of fact, walls of mountains, some 1,000 or 3,000 feet in height, whereas the wall or basin is merely one of the results of the river denudation of the area of varied and softer strata behind the less destructible band of mountain rocks.

depth of at least 3,000 feet, thus leaving a deep, though wide, upward sloping V-shaped pass or gorge of about 2 miles in length through the Eastern Ghâts.

Approximate age of river valley.

The late Dr. Oldham long ago communicated the view that the great drainage basins of India were on the large scale marked out and existed as drainage basins at the enormously distant period which marked the commencement of the deposition of what we now call the Gondwána formation, and he considered the Pennér valley as one of these larger basins, though no traces now exist, and perhaps never did, in its valley of any Gondwána strata. There are, it is true, the patches of Rajmahal (jurassic) shales occurring out on the plains towards the coast, to the north and south of the river, but these do not necessarily bear on the age of its basin. I have, however, already shown how the plains and ghât step of the Coromandel probably existed in early mesozoic times, and this, taken in connection with the occurrence of the plant-remains, seems to favour the view that the Pennér valley was then in existence also. This is, I think, all that can be safely said of the age of the Pennér valley in reference to Dr. Oldham's generalization, though as regards the marking out of that valley in the Cuddapah district and in the eastern portion of the Bellary district covered by the same transition rocks, it is possible to conceive a much earlier time, following almost immediately on the elevation of these supposedly very early palæozoic rocks.

The delta of the Pennér.

The Pennér has a narrow strip of alluvium along either bank as far back as the Somasilla pass or gorge, but the first spreading out of its deltaic deposits occurs at Sangam. There is, however, really very little of a fair delta at the mouth of this river, for it does not sub-divide into two or more streams until within about 10 miles of the seashore, a feature which seems to me to indicate that the alluvial deposits must after all be greatly eroded, and that we have here only a portion of the original delta. The Swarnamukhi and the Kandléru have nearly as large deposits of alluvium spread out around their mouths, and they join with the Pennér and the other

small streams in having formed the great unbroken stretch of alluvium here lying along the whole coast. The courses of these rivers in their alluvial flats all trend to the north-east, or with the prevalent currents along the coast.

The Pulicat Lake and its origin.

The most remarkable feature of the coast connected with the alluvial deposits is the extensive, but very shallow, hollow of the Pulicat Lake, which has only one small stream flowing into it near Sulúrpet, while the Narnaveram river at the extreme south end keeps it open to the sea. One way of accounting for the existence of lagoons such as the present, is that a hollow must have been left in the contiguous alluviums of two rivers which was eventually lapped round by their outspreading and rising deposits, though still kept open by minor streams flowing into it. Such is apparently the condition of things which went on in the formation of the Colair Lake between the Godávari and Kistna deltas. But in the case of the Pulicat Lake there is no such evident leaving of a hollow between the great rivers, though the suggestion that this is an analogous case to that of the Colair Lake is more valid if we suppose that a considerable area of alluvial land has possibly been removed from the eastern side, and that the Swarnamukhi and Palár (in the Madras district) may have been the great alluvial distributors to the north and south.

The small extent and shortness of the delta of the Pennér when considered with regard to the length and drainage area of this large river and the generally even width of the alluvial belt along the coast, seem to point also to the former existence of alluvial land considerably to the eastward of the present coast line. It is to be noted that though six great rivers, *viz.*, the Cauvery, Pennár, Palár, Pennér, Kistna, and Godávari, flow out on the Coromandel, yet only three of these have decided and extensive deltas; the next largest, the Pennér, having only a very small one as proportioned to its importance, in fact, as I suppose, a reduced delta, while seaward shoals are prevalent along the adjacent coast, especially at Armogamor[1] and opposite Ramiapatam and Ongole further to the north.

[1] The "shoal is about 10 miles long, the shallowest part is $1\frac{3}{4}$ fathoms; and it lies from $3\frac{1}{2}$ to $5\frac{1}{2}$ miles east-by-north of the light-house."—*Manual of the Nellore District.*

Correspondence of physical features with arrangement of rock series.

The partially parallel arrangement of the land features in broad or narrow strips of hill and plain is, as already incidentally noticed, dependent on a more or less banded distribution of the later formations over the gneisses which give the most important and extensive outcrop, having a width of some 40 miles between the low plateau ridge of Nellore, &c., and the Veligondas.

The oldest covering rocks or the Cuddapah series, consisting of detrital quartzites and slaty beds, are very clearly displayed and defined in the western mountain belt, though there are some important outliers in the Kambák and Kálahásti ranges to the south-south-east and again in the Udayagiri Droog and the Dargadevi Konda to the north of the Pennér.

The next later formation is merely represented by the barest traces of shales belonging to the Rajmahal group of the upper Gondwána system, which are here exposed in well-sections at only a few spots underneath the lateritic band of Nellore. At the same time, it is quite possible that these small patches are part of a hidden belt connecting similar strata in the Madras and Kistna districts.

Over these and covering them comes the broken strip of sandstones and laterite forming the narrow plateau ridges running parallel with the coast, on one of which the town of Nellore is situated. These sandstones are rangeable with the *Cuddalore sandstones*, distinguished by Mr. H. F. Blanford as a group overlying the cretaceous rocks near Cuddalore, or with my Rajahmundry sandstones[1] in the Godávari district, which overlie rocks whose fossil "relations appear to be rather with the upper cretaceous rocks of South India,"[2] and are therefore presumably of tertiary age.

Of recent deposits, there is the belt of alluvium bordering the eastern edge of the sandstone plateaus just noticed; and of yet newer age comes the thin strip of blown sands on the sea-shore.

[1] Rec. Geol. Surv. of India, Vol. X, p. 56.

[2] Manual of the Geology of India, p. 319.

This general sub-division of the crystallines is quite clear in the northern part of the Carnatic: in the south-west corner of the present field, that is, in the Venkatagiri and Kálahásti country, the rock is a hard massive granular crystalline gneiss, of pale-flesh and grey colours, with little or no foliation, while on the other hand schistose gneisses are in great force all over the middle of the field, in eastern Kálahásti and the taluqs of Gúdúr, Nellore, Rápúr, Kávali, and Udayagiri.

Succession of these.

These gneisses also appear to be associated in a fairly serial order, though, as is usually the case in South India, no good boundaries are recognisable, the change from one to the other group or sub-division, often within a narrow width, being nearly always gradual. Such want of definition would necessarily occur between the more highly granitoid or irregular crystalline aggregates and the less distinctly foliated masses, the metamorphic action having been presumably more intense in these rocks: but as the more and more distinctly foliated gneisses are met with, as here and further north in the Kistna and Godávari districts, it seems to me that boundaries are becoming more evident, and will ultimately be recognisable down south when more time can be devoted to the examination of these rocks.

The mountain gneiss of Southern India not represented.

A distinguishing feature of the Nellore gneisses is that they do not number among them a good representative of the massive grey syenitoid or hornblendic rock which is so persistent in the mountain ranges of South India, and which shows in diminishing force nearly as far north as Madras, but which, by its absence here, may perhaps be indicative of a much more important separation of the gneisses of Venkatagiri and Gúdúr than is evident in the field.

A classification of the Nellore gneisses.

The Nellore foliated rocks may then be considered under the great sub-divisions of the *Massive* and the *Schistose Gneisses*:—

4. Micaceous, talcose, and hornblendic schists, with few quartz-schists or quartz-rocks	SCHISTOSE GNEISSES.
3. Foliated gneisses, with frequent quartz-schists or quartz-rocks	
2. Grey gneiss (sometimes porphyritoid)	MASSIVE GNEISSES.
1. Red granitoid gneiss	

This serial order is, however, to a certain extent, rather arbitrarily made out in accordance with the received scale of metamorphism, the most crystalline rocks being assumed to be the older. The real condition of affairs is that though the schistose groups are to all appearance overlying the red and grey massive gneisses, yet the much more schistose group (4) is situated between the latter and the group (3) apparently overlying both. There seems, besides, no reason, in this field, to question the succession deduced from varied stages of metamorphism, since this association of the groups is explainable on a faulted position of the younger strata (4) against the massive and older gneisses, or a former condition of extreme unconformity by overlap between the latter and the schistose gneisses.

Correlation with the gneiss of India.

Our observations of the crystallines are as yet too few and scattered to admit of any good attempt being made at a correlation of these Nellore gneisses with others in the Peninsula, though it would appear on the whole that they belong to the newer of the two series of the peninsular gneisses, namely, that of the main or eastern area.[1]

At the same time there are many features about the massive gneiss of the Swarnamukhi valley or the granitoid gneiss (1) which point to a comparison with the late Dr. Stoliczka's central gneiss of the Himalayas.

With Scottish gneisses.

Subsequent to my survey of this field, I had an opportunity. when at home on furlough, of visiting the neighbourhood of Lochmaree, in the western highlands of Scotland, which has been rendered famous by the controversy between Sir Roderick Murchison and Professor Nicol on the differentiation of the Laurentian and palæozoic gneisses occurring there; and as far as observations on the rocks of such immensely separated countries can go, it appeared to me that the similarity between the gneiss (Laurentian) of Lochmaree and that of Venkatagiri and Kálahásti is remarkably close, while the schistose group of the Nellore district is comparable with the Silurian

[1] *See* Manual of the Geology of India, pp. xviii, xix, and p. 17 *et seq.*, Part I.

gneiss. This is, however, all that can be safely said at present, for unless the observer is acquainted by very long and careful surveying with the gneiss of both regions, his comparison of their rocks can only be very general. The one great characteristic or feature of the older Scottish and Lewisian gneiss is its persistent transverse strike to that of the superincumbent gneiss, the most absolute condition of unconformity; but this cannot be cited as existing among the Madras crystalline series; for, as far as we yet know, there is no marked deviation of strike in any of the gneisses, and the Cuddapah rocks, however unconformable they may be to their subjacent crystallines, have always very much the same strike. Hence in this one particular point the comparison of the Madras gneisses with those of Scotland loses much of its significance.

In the following more detailed description of the rocks, that of the country north of the Pennér is taken from the progress reports left by Charles Æ. Oldham, while that of the country south of the river is mainly from my own work, though here also a good part was surveyed by my colleague.

The massive gneiss of the Swarnamukhi.

The red massive or granitoid gneiss.—The massive red gneiss, or granitoid form, occupies but a small portion of the south-west corner of the field along the valley of the Swarnamukhi and northwards past Venkatagiri, whence it is traceable westward right into the upland of North Arcot and Cuddapah. Its eastern edge is ill defined, but it may be considered to run from below Batanaik Konda in a curving north-north-west line, a short distance to the west of Kálahásti and Venkatagiri, after which it passes under, or becomes the floor of, the Transition Series, only showing again very slightly to the north of the Pennér.

This gneiss is generally a close-grained aggregate of quartz and felspar (orthoclase, ? oligoclase and a little albite), hornblende being often scarcely discernible, while mica is even more rare. It is thus very like a binary granite, only it is perhaps more generally smooth and rounded on its weathered surfaces than the granite occasionally traversing it, the latter being very often more distinctly and largely crystallized (felspar easily

recognisable), or again very fine-grained and then sharp and smooth in its outlines and surfaces. The quartz is of white colour, in two forms, dull and amorphous or glassy, while the felspar is generally of pale flesh-colour, or occasionally of a dull white, the rock itself being essentially of a pale reddish colour. It is very hard and compact, and requires most laborious chiselling when being dressed, but is easily hewn into large blocks by wedge splitting, a practice which is or was very common, for wherever there is a mound or hill of this gneiss, there are often old trenches whose sides show the holes originally cut for the reception of the large iron wedges. It is this variety of gneiss which oftenest gives the *roche-moutonnée*-like form to many of the hills, and in this feature[1] it answers somewhat to the "dome gneiss" of the northern area of the Bengal gneiss. Foliation is very faint, but what can be made out in the Venkatagiri country is generally north-south in its direction and vertical: here also signs of bedding are rare. Perhaps along the southern edge of the field, on the right bank of the Swarnamukhi, the rock would be considered more like gneiss, for here there is occasionally distinct and wavy foliation.

Jointing is developed at wide intervals in the rock generally in north-north-east to south-south-west and east-by-north to west-by-south directions, the latter having the lower dip 60°—75° southward.

Granitic and trappean intrusions.

Granitic and trappean intrusions are not common, or rather they are not often visible here owing to the area being in part a river valley and much covered up by superficial deposits. Dykes of compact and porphyritic greenstone are however often visible in the Swarnamukhi valley, particularly on the left bank at Kirkambádi and thence eastward and westward on the right side of the valley. Eastward of Púdi (on the railway just south of map) there are again many east-west dykes of greenstone, this locality being just on the eastern edge of a very remarkable and extensive development of trappean intrusions in that part of North Arcot. In the banks of the large nala about 3 or 4 miles eastward of Kirkam-

[1] Manual of the Geology of India, p. 20.

badi there are frequent outcrops of granitoid gneiss much cut up by numerous easterly and westerly small granular veins of white quartz with pale yellow-green pistacite. Irregular strings of white quartz, sometimes tolerably straight but oftener curved and branching, are common in this gneiss.

The grey gneiss of Kálahásti.

The grey massive gneiss.—To the eastward of the boundary indicated as striking a short distance westward of Kálahásti and Venkatagiri, hornblendic strings and nests begin to show in the red gneiss, and hornblendic foliated rocks crop out of the wide-spread superficial coverings of this part of the country, after which the prevalent rock is a grey gneiss. This is in point of fact all that can be said of the change from one variety to the other of the massive gneisses, though there is no doubt that to the right or left of this vague line, or rather extremely narrow interval, the rocks are decidedly different in structure and constitution. The dip of the two is eastward, their lie being very often vertical: so that in serial order, the grey gneiss is apparently above or younger than the red gneiss.

The grey gneiss forms a band of from 10 to 20 miles in width, alongside the red granitoid rocks as far north as Rápúr, after which its course is broken by the intervention of transition rocks, while there are sudden alterations in the rocks of the band itself. The general north-north-west run of the strike at the same time carries this band under the strata of the Veligondas, and the outcrop north of the Pennér is only very narrow.

A certain likeness to the massive gneiss of Southern India.

While working at this division I was fain to consider it a syenitoid gneiss in contradistinction to the granitoid rock, from its being occasionally like the syenitoid rock of the Nilgiris and other mountain ranges of Southern India; but it is here more generally a foliated rock, and thus perhaps rather to be ranged with the foliated gneiss of the low country of Coimbatore and Salem.

There is more variety in the rocks of this band than in the red gneisses, but the more prevalent form is a massive rather rough gneiss of quartz felspar and hornblende, arranged more or less distinctly in a laminar manner, the laminæ or irregular folia being seldom continuous for any extent, unless they are thick, and then they are mainly of quartz or felspar. Foliation of this kind can generally be distinguished over a tolerably large surface of the rock, but with difficulty, and it is occasionally so obscure that the syenitoid character is then very striking. This form is never so essentially syenitoid, that is, hornblendic, as the mountain gneisses of Southern India, nor is it so well laminated or schisted as is often the case in the low country between these mountain masses.

More varied than the red gneiss.

In the neighbourhood of Kálahásti, or on the western edge of the belt, there are frequent outcrops of a more laminated or foliated rock, with fair hornblendic strings and nests, and towards Venkatagiri and to the north of that place this begins to show in greater force until about Rápúr. In the southern part of this band the syenitoid variety is often more compact, rather pasty and full of small rounded or bean-shaped masses of pale grey or white felspar, thus assuming rather a porphyritic character. In the neighbourhood of Kálahásti and northwards from the Swarnamukhi, it becomes more crystalline and coarse, the minerals occurring in larger masses.

The long bay of gneiss running southwards between the Kálahásti ridges and the larger Kambák range shows abundant outcrops and masses of this compact porphyritoid rock, with kernels of white felspar ranging through it in north-north-west to south-south-east laminæ, in the long hog-backed hillocks and ridges in the neighbourhood of Royagunta or in the flatter-rounded exposures among the villages 4 or 5 miles west of Kálahásti. At that town itself, on the right bank of the river, a more granitoid form of this gneiss shows under the small hill to the north. The porphyritoid variety also forms a short width of the low country on the eastern side of the Kambák range.

Porphyritoid gneiss of Kálahásti.

Breaks in continuity of strike.

North of the Swarnamukhi there is a very marked belt of the same porphyritoid and, now, rather pasty gneiss running north-west of Kátcheroo to the Kyoor tank for a breadth of nearly 4 miles, in which position, however, and with which dimensions it cannot be said to be quite continuous with the wider spread of outcrops in the Kálahásti and Kambák area; neither are there any fair indications—partly owing to the wide covering deposits of the river—of any curving round in the strike of the foliation of the Kálahásti outcrops as towards a contraction into the Kátcheroo width. Contraction and even displacement must, however, I think, have taken place, for there certainly are evidences of such in the Kálahásti ridge and in the curious narrow strip of detrital quartzites of Pillaméru to the north which has evidently been wedged in here in a most abnormal way among the gneisses.

The porphyritoid belt changes about Rápúr.

Beyond, or to the north of the Rápúr tributary of the Saidapuram river, the Kátcheroo-Kyoor belt of grey gneiss either dies out altogether or becomes so much altered or changed, or replaced by igneous-looking rocks, as not to be fairly recognisable. The mass of the rock is a pasty-looking aggregate of hornblende, with a little quartz and felspar, and is more of a porphyritic syenite, but towards Bodanapali it becomes even more compact and pasty, and then looks more like a grey bedded trap, though it is still full of little masses of grey felspar, and such rock is found extending into the bay of quartzite hills between Gelacapád and Bodanapali.

Interruptions of transition rocks, and faulting.

For a few miles further north there are only slight traces of a somewhat similar rock, the country being for the most part of abnormally placed quartzites of the Cuddapahs among micaceous and hornblendic schists much traversed by a west-north-west to east-south-east system of trap dykes; but beyond this point, though there is still great similarity of constitution in further outcrops in the ridges extending from Sudamulla past Panumurti, I do not feel justified in carrying this member of the grey gneisses. There is every evidence that a strong fault runs across this part of the country east-north-east from Rápúr, by which the continuity of the Venkatagiri-

Saidapuram strata is broken, for to the north of this line the grey gneisses are found more to the westward running close up alongside the talus of quartzite debris below the Veligondas and so filling up most of the narrow valley extending north from Rápúr to the Pennér, while the schistose belt of gneisses next to be described has also been thrown more to the westward.

The Schistose Gneisses.

A tolerably close boundary can be drawn between this group and the massive gneisses from the southern edge of the area up to Rápúr, but thence to the Pennér the junction is covered up or obscured, the transition series likewise coming into juxta-position with it, while both are so crushed and metamorphosed that it is extremely difficult, if not quite impossible, to say exactly to what series they belong, and it is clear that both have been contemporaneously altered.

Change in the dip.

At this boundary the lie of the schistose gneisses is with that of the Massive Series, namely, with a high dip to the eastward and having a general north-north-west to south-south-east strike; but after a short distance eastward the dip is soon reversed, and nearly all over the rest of the crystalline area the beds are dipping westward at generally high angles or are vertical, while the strike becomes more due north and south and is only in very rare cases ever to the east of north.

Lithology.

This sub-division consists in great part of hornblendic, micaceous, talcose, or chloritic schists, or well-foliated or laminated and more massive gneisses with varying proportions of quartz, felspar, hornblende, and mica; while there are very many subordinate beds of laminated quartz-rock or quartz-schist approaching very closely to detrital quartzites.

An eminently schistose band.

A fairly distinct band of more eminently schistose rock occupies the western edge of the field, the schists being talcose, chloritic, and micaceous, with frequent intercalations of hornblendic bands, throughout which is disseminated a tremen-

dous deal of quartz in the form of irregular segregations and very indistinct veins. The micaceous and talcose forms occur in greatest force on the right bank of the Pennér, between Káluvaya and Thálagapur, whence they run to the south-east as a narrowing but tolerably distinct set of strata as far as Saidapuram. About halfway down the southern course of these, and on their western side, come hornblendic schists, occasionally massive (coarsely crystalline with radiated assemblages of short needles of hornblende), but mainly schistose and acicular, and these gradually increase in width and persistence down to the Swarnamukhi. To the north of the Pennér the hornblendic and more highly schistose bands are not quite so distinct, though they are traceable as such for some short distance on towards Udayagiri.

Less schistose band.

Eastward of a line drawn from the latter village past Yarabali on the Pennér through Tummulatalupúru to Ojili on the Swarnamukhi, the rocks become gradually coarser and more distinctly bedded, though there are still frequent intercalations of fine mica schists with a more quartzose constitution, with separate beds of quartz-rock or quartz-schist.

Garnetiferous band, cupriferous.

About Saidapuram and Tummulatulapúru there is a strong run of garnetiferous strata, and this is traceable at intervals right up to the northern edge of the sheet, where also are associated cupriferous schists well known as the copper beds of the Nellore district. The garnets in these beds are sometimes quite remarkable in their size, beauty of crystallization, and number.

Ridges of massive gneiss.

Towards the line of Nellore and Gúdúr, a few thin outcrops of more massive grey gneisses of quartz felspar and hornblende occur, and these are, if anything, in greater force to the northward on the other side of the Pennér near Buchireddipalem, where this rock has been quarried for the new pagoda at Nellore. With this exception, however, there are no strong or distinct representatives here of the more massive gneisses of the Madras, South Arcot, and Trichinopoli districts, which are more apparently represented, however poorly, by the Kálahásti outcrops of the massive crystallines.

Style of the gneiss north of the Pennér.

To the north of the Pennér, the succession of the foliated gneisses lying to the eastward of the more eminently schistose band is in tolerable accord with that just described for the middle area, but here the series has widened out considerably until it occupies almost the whole northern edge of the field, the strike of the foliation or bedding being, however, more regular and northerly. This great increase in width is in part accounted for by the more frequent intercalation and greater thickness of the subordinate quartz-rock or quartz-schist beds which here become quite a marked feature in the district, and give rise to many and distinct hilly ridges.

The subordinate quartz-schists.

The remarkable and unique feature in the schistose crystallines as a series, is the presence of these subordinate beds of quartz-rock or quartz-schist, and these attain an additional interest from the fact that they, in the middle area, that is, between the Pennér and the Swarnamukhi, are to all appearance a perfect graduating set of beds, from manifest coarse quartz-rock to fine compact quartzites, very similar to those in the Cuddapah or Transition Series. To the north of the Pennér also, the beds as they are crossed westward become finer and finer-grained until they are compact waxy quartzites on the western edge of the foliated gneisses; but there do not appear to be any fair cases of conglomerates or pebbly beds, or even of ripplings, though the resemblance to the Cuddapah quartzites is otherwise most remarkable.[1]

[1] Captain Newbold also noted the character of these quartz-schists, writing of the neighbourhood of Sangam on the Pennér, and the rocky ridge there running down into the river: "It is composed * * of a massive quartz rock in indistinct stratification, cleft occasionally, like the laterite, by intersecting partings and vertical fissures which divide the rock into parallelograms. * * This quartz rock passes from opaque and granular to compact, translucent chert of various shades of red, brown, green, and white. It contains disseminated scales of mica of a golden colour, which glitter like those in avanturine, and nests of brown iron ore.

"If the marly (? nearly) horizontal partings are really the planes of stratification, it may be inferred from its conformability that this quartz rock does not belong to the hypogene series which is seen in highly inclined beds near its base, penetrated by veins of granite (as seen at Pollium, a village between Doroor and Sangam), but that it is an altered outlier of the sandstone mural crests which are seen from this on the western horizon capping the granite and hypogene schists of the Eastern Ghauts."—*Jour. As. Soc., Bengal, Vol. XIV, 1845. p. 398* et seq.

Difficulty of distinguishing these from the Cuddapah quartzites.

The difficulty indeed was at last to decide what we should consider as quartzites of the one series or the other, for it was soou found out that along the outer edge of the transition rocks recognisable, Cuddapah strata are associated with the gneisses in a most obscure way, even to their having apparently been wedged or let in as thin strips among the gneisses. Mr. C. Æ. Oldham appears to have relied principally on the micaceous constitution and the cleaved character of the beds in the gneiss, though such characters are common enough among the manifestly detrital quartzites well into the interior of the Cuddapah area. I myself was rather guided by the untoward positions of fairly rippled and pebbly beds in my recognition of them as transition strata, and by the continuance of strike with the gneiss for tolerable distances, or association with hornblendic beds, as distinguishing features of the gneiss quartzites; though even with these guides I was continually thrown out by the knowledge that the different quartzites could be quite easily thrown together by faulting among the hornblendic rocks, as in fact is often the case with them between Káluvaya and Paremkonda.

Lithology and distribution.

The succession or changes in the subordinate quartzites may, however, be perhaps best shown by the following details taken in the country westward of the town of Nellore; and the same style of beds is traceable to the north of the Pennér and in the Swarnamukhi region, though in this latter direction they are much, and eventually completely, covered up by superficial deposits.

The Narasimhakonda quartz-rock.

To the west of Nellore, in the rather picturesque ridges of Narasimhakonda, there is a strong development of thick beds of quartz-rock among schistose gneisses. Here the rock is a massive pale-brown or white, occasionally ferruginous, usually very coarse granular crystalline aggregate of quartz, sometimes not at all unlike a vein quartz. Still it is not so massive but that there are small ragged and irregular crevices between the glassy and semi-translucent particles of quartz which were once in part occupied

by mica. There are coarser and finer beds, but no approach to a dense fine-grained quartzite, and in the less coarse beds lamination is recognisable; though, on the whole, the sedimentary origin is only manifest in the distinctly and for long distances bedded character of the rock among the other gneisses. The debris of these beds scattered over the flats below the ridges is quite as peculiar as the rock itself, being a sort of sharp gravel of glassy quartz. This Narasimhakonda quartz-rock is easily recognisable all over the district. To the west of these ridges are further beds of this rough quartz-rock, which show better to the north-west at Tárndipali as they drop down to the Pennér alluvium. The beds here are still of the same character as those of Narasimhakonda, very coarse, crystalline, glassy, and laminated. Still going west, a strong band of frequent out-crops and ridges of quartz-rock runs from Suripalem on the right bank of the Pennér, south and south-east through Nandiwai, Lingumpilly, and Davanavamur to the Kandleru valley, which still possess generally the character of the Narasimhakonda rock, but have frequent intercalations of finer and more compact strata. This band is the eastern arm of a fan-like or divergent strike of the foliated gneisses which commences at and spreads northward from Ingoort, and it will be seen further on how the rocks vary in the western arm.

Finer and compacter varieties about Ingoort.

In this the Ingoort neighbourhood, the first ridge west of Lingumpilly[1] is of various styles of quartz-rock, from the very coarsely crystalline to the more compact granular, among which are lenticular seams of schistose hornblendic beds. There are compact grey and yellowish quartzites, looking like strings of vein quartz, running in the bedding, and, again, coarsely crystalline granular rock like that of Narasimhakonda. About a mile further west the main or highest ridge forming the western side of the Ingoort nucleus is almost entirely made up of thick beds of pale grey and greenish quartz-rock or quartzite, a quartzite which more and more

[1] Among the ridges west of Lingumpilly there is a poor outcrop of beds of grey crystalline limestone striking north-no th-west with a vertical dip.

resembles the dense and fine granular rock of the Transition Series. At the highest point of the ridge these are nearly vertical, and show faint traces of ripplings. To the west of Ingoort, frequent beds of quartz-rock, with micaceous partings and laminæ, occur among garnetiferous hornblendic schists. The northern end of the Lingumpilly ridge is composed of beds of almost pure white or bluish-white coarse crystalline granular quartz-rock with scales of silvery mica running through it. In a low ridge about 2 miles north-east of Lingumpilly, there are beds of a beautiful bluish-green semi-translucent saccharine quartz-rock. The western branch of the Ingoort divergence runs up and meets the Pennér about Pátapád, where at the north end of Ulavapali tank are beds of granular-crystalline grey and buff quartz-rock, less coarse than that of Narsimhakonda, but not so compact as ordinary Cuddapah quartzites. In the same neighbourhood, Pálacole ridge consists of beds of slightly micaceous quartzites, much contorted in the strike of the bedding. Near the bottom of the ridge on the eastern side, there are some thick beds of compact dark-bluish-grey quartzite, and the same beds appear, but riddled with strings of white quartz, at the foot of the Mámadúru ridge. This last ridge runs right up to the Pennér alluvium, and is made up of successive beds of flaggy micaceous quartzose gneiss, micaceous and talcose schist, and quartz-rock.

Micaceous.

Saccharine.

As the rocks are now examined westward, the quartz-rocks, or rather more generally quartzites, become much more frequent in thinner bands with thinner beds or even flags; while the proper gneisses are becoming more finely schistose and less quartzose as the more decided band of fine schists is approached. At the same time, there is a greater frequency of trappean and trappoid outcrops accompanied by a marked occurrence of epidote or pistacite through the strata, the quartzites occasionally being quite green-coloured from the amount of this mineral distributed through them.

Epidotiferous or pistacitic quartz-rock.

Southward of Dásúr there is a narrow and rugged little ridge

of very vitreous-looking quartzites much split up by jointing and contorted. In the south-west side of these beds is an outcrop of jaspery quartz-rock with epidote. In the stream between Dásúr and Purvatipuram there are schistose quartzites. Further south-south-west and to the south of Kumarigunta, these seams or beds of quartzite are intercalated with talcose and chloritic schists. Between this and Tummulatulapúru very little rock is seen owing to the superficial coverings, except in the beds of the larger Ingoort nala and that south of the first village, where occasional interesting sections are exposed of the clear association of these quartzites with the schistose gneisses. In the nala south of Tummulatulapúru beds of quartzites and gneissoid rock are continued past and due west of the village, and close by here is a band of pale-blue and grey waxy quartzite, which is slightly rippled. As this belt is followed south-east, we again pass from the more compact and quartzite forms of this rock to varieties approaching the Narasimhakonda type.

Waxy quartz-schists, rippled.

To the westward of Túramulla there are two rocky ridges composed of beds of white grey and greenish waxy-looking quartzites, associated quite conformably with the schistose gneisses. These are as like quartzites of the Cuddapah series as possible, the only difference being that they are, if anything, more crystallized and sugary-looking. They are distinctly laminated and occasionally false-bedded, but there are no signs of conglomerates or pebble beds. The continuation of these same beds shows east of Tummulatulapúru, when they are still exceedingly like transition beds, while they are furrowed slightly on the bed surfaces either as ripplings, or as crumplings from lateral squeezing, the furrows being long and parallel to each other, though they also run into each other after the manner of ripplings.

Close similarity to the Cuddapah beds.

Lastly, at the southern end of this band, there is a remarkable case of variation in the style of these quartz-schists in a very obscure case of an apparent conglomerate. At

Conglomeratoid gneiss.

Shamudtha, about 4 miles due south of Saidapuram and at the north end of the tank, there is a ridge of highly micaceous quartz-rock, the bedding striking north-north-east to south-south-west, and the dip being an undulating or rolling one. The massive quartz-rock is occasionally weathered into what appears to have been a coarse conglomerate of big quartz pebbles with their longer axes in the direction of the strike. These lenticular rounded masses are thickly coated with silvery mica, which is stringed out as it were along the laminæ; close by and east of the quartz-rock there is a schist in which the mica preponderates over the quartz to an enormous extent, and beyond these are dark-green chlorite schists. I think this can hardly be considered a conglomerate, particularly as to the north, in the same line, compact quartzites occur of a clear conglomeratic constitution. It is more probably a case of micaceous quartz-rock showing a very exaggerated form of segregation of the quartz in rude spindle-shaped masses—just as the quartz in ordinary coarse micaceous schists is often found assembled in small lentil-shaped masses—around which the mica is gathered and runs thence in the laminæ of the rock.

The original condition of the quartz-rock or quartz-schist beds is often shown in the weathered outcrops, a very good display occurring in the bed of the nala running past Védanapurti some 6 miles north of Dásúr, where the section gives a series of schists and shales of pale-green, greyish-green, and dark-green colours, with grey, yellow, and yellowish-red sandy shales, the latter being merely weathered quartz-schists and exactly like recent sandy shales.

A gradation in the series evident.

Thus far, I think, it is fairly clear that there is a gradation in the quartz-schists from the excessively coarse beds of Narasimhakonda through more and more compact beds to the sugary and then the waxy form of quartzite, and even to fairly rippled and pebbly beds, though coarse granular crystalline forms are still met with here and there with the denser strata.

However, this gradation runs closer in the neighbourhood of the boundary between the crystallines and the transition series; and here I must allow the great difficulty there is in distinguishing the quartzites

of one or the other series, while to some extent my discrimination has been more guided by the experience gained while working over such rocks in the field. It is a well-known fact, as may be fully exemplified in the experience of some of my colleagues, over the Gondwána groups for instance, that one can very often tell to which members certain very similar-looking rocks belong, without being able to explain why he so recognises them; and it was thus with both Mr. Oldham and myself after some time among the rocks of this field. There are certain outcrops of quartzites which we were not able to discriminate, and which possibly never can be relegated with certainty to one or other series; but these are either on or very close to my approximate boundary, and they are so small as to have little or no effect on the main division.

The pistacite quartz-schists.

A very curious band of quartzose rocks, already slightly noticed, occurs just east of the boundary, among the hornblende schists, which are highly charged with epidote, either in a minute way so as to give them a green colour: or with the mineral scattered through them in the lamination: or irregularly, like the garnets in a garnetiferous schist, when also the beds sometimes assume the appearance of a vesicular igneous rock, the epidote having weathered out leaving small cavities. These quartzites occur as a narrow band among the schistose acicular hornblende rocks and traps of the more finely schistose crystallınes running through Dásúr nearly to Túmoy, and again—possibly by a throw—further to the eastward of the latter village from Thocapalem south-eastward. This form of quartzite is often so hard and compact that it looks almost like a jaspideous rock, and in my notes I find it often referred to as jaspery quartzite. It occurs frequently in the schistose gneisses between Yarabali and the boundary at Káluvaya, and thence southwards as far as the Kaudléru river, always associated with hornblende schists and occasionally with what I cannot consider as other than strong intrusive sheets of diorite; but they are in greatest force in some low ridges extending from Dásúr past Túmoy, where also there is a great deal of extravasated trap. Again to the south of Thocapalem, on the Túramulla stream about Chinapalem and westward

of that village, pistacite quartzites are also common, but always associated with schistose and massive hornblende strata, while there is also a further development of the trappean intrusions, this part of the field being just at or near the south-western extremity of the greater trappean development yet to be detailed as extending diagonally across the Swarnamukhi-Kandléru country. Certainly the pistacitic character of the quartzite band seemed to me to be intimately connected with the stronger development of intrusive trap along this particular line of country; but there are features against this view, such as that the quartzites of both series alongside or on the trappean development of the Swarnamukhi-Kandléru country are not charged with epidote, nor are those above and below the traps with intermediate pistacitic band extending south from Káluvaya. The more probable view is that we have here a set of quartzites charged with an accessory mineral in a similar way to that of the garnetiferous quartzites and schists a little further to the east, the association of them with the traps being merely a coincidence.

Iron-stone quartz-schists.

To the south of, or on the right bank of the Swarnamukhi, the schistose band becomes industrially important through the occurrence of a rather strong development of quartzose iron beds in the ridges extending from Tresulmare to Ircolah, when they are in association with, apparently above, a thick series of hornblendic schists. These are traceable again on the left bank of the Swarnamukhi and run up alongside the great trappean outburst, and are probably, though now broken across and displaced, a continuation of the Dásúr series. The proper iron-stone band is on the west side of the ridges extending from Tresulmare, where, however, the country is flat and the outcrop of the beds is only seen in the flat ground below the tank of that village. The rocks on the western side of the iron-stone band are all hidden by alluvial and superficial deposits, but on the eastern side there is a broad belt of the hornblendic schists touching on the great northern high road, and the more acicular form of the hornblende rock is again to the east of this band about Rásanur and Coonrum.

The beds are thick and numerous, consisting of laminæ of quartz and grey iron-ore weathering into the brown or red hematites—more usually the brown peroxide—, the laminæ being often thick and very distinct, with occasionally a brecciated character, angular fragments of quartz being cemented together in a ferruginous matrix. At the Iroolah end of the outcrop the laminæ of iron ore are well weathered out, leaving the surface of the rock curiously roughened by outstanding and wavy little ridges of quartz. Small smelting furnaces are set up at Rásanúr and at the neighbouring villages of Connoor and Mahulpadi, the latter, though some 8 miles to the north-east, obtaining its ore from Rásanúr. I did not see that any excavations had been made in the beds of ore; the people, as in most other iron districts, only work at the debris and more weathered portions of the out-crops, where they can get fragments of ore with the smallest cores of the hard grey oxide, and from which the siliceous particles have been well weathered or loosened.

Great development of quartz reefs.

The neighbourhood of the boundary between the two gneisses, and again between the newer gneiss and the transition series, is marked by an extraodinary development of small reefs or veins of quartz which nearly always run for short distances apparently with the strike of the foliation or bedding, though their generally real lie is with an ill-defined north-north-west to south-south-east cleavage, having a low dip to east-north-east. These reefs are more frequent on the schistose side of the gneiss boundary, and they are developed to a most remarkable extent on either side of the line between the foliated gneisses and the transition rocks for a width of 7 or 8 miles. It seems quite evident that this development of quartz followed on or took place during the period of movement or crushing up and fracture of the transition series, though it has not followed the present lie of these rocks. The probability is that the line of disturbance was more nearly with the boundary between the gneisses thus striking from Gelacapad to Kálahásti, while the present fainter occurrence of quartz in the gneisses is only the dying out of a southern extension of

the northern development which has been denuded from the Vekatagiri interval. The material of these reefs is nearly always white quartz, much cleaved and fissured, giving very sharp and acute-angled debris in long fragments and splinters. There is often a good deal of schistose talc and chlorite fragments distributed through the veins; and small strings or minute specks of micaceous iron ore are common. I only saw the faintest traces of green carbonate of copper, or of copper pyrites, in the quartz associated with the massive traps between Yarabali and Káluvaya; but, as will be seen further on, it is rather in the traps themselves that the ores of copper occur in this district.

CHAPTER IV.—THE TRANSITION SERIES.

Cuddapah Formation.

This series occupies only a very small portion of the country, as compared with the gneiss area, while it can be defined very simply as a set of quartzites and slaty beds belonging to three or more groups of the Cuddapah formation. Full details of this Madras member of the transition rocks are given in the Memoir[1] devoted to its description, the classification or grouping therein laid down being as follows, in descending order :—

Cuddapah formation ...	4. Kistna group.
	3. Nullamallay group.
	2. Cheyair group.
	1. Paupugnee group.

The Cuddapah groups in this area.

The lowest of these groups is not, as far as is kuown, represented in the present area, but the strata of Kambák Droog, the Kálahásti ranges, and the Veligondas as far north as the parallel of Venkatagiri, are of the Cheyair group. A further reach of the Veligondas, as far as Rápúr, is made up of succeeding beds of the Nullamallay quartzites and slates, and the rest of this range represents the Kistna group. The eastward outliers of this range and

1 Mem. Geol. Surv. India, Vol. VIII, p. 1.

some small outcrops in the low country are of undecided age, but they may be of the Cheyair and Nullamallay groups.

Age of series.

No fossils have as yet been discovered in these rocks, or in their representatives in other parts of India, so that the little that is definitely known of their possible age is only ascertainable from their stratigraphical relations. In this field itself they are not directly associated with any other formations, but in the Cuddapah district they are unconformably overlaid by the Kurnool series, which is again unfossiliferous. In the adjacent Madras district they are, I think, directly overlaid by the upper Gondwána beds; and in this area, these beds, or the plant shales, contain pebbles of the Cuddapah rocks. In the Godávari district, the representatives of the Kurnool and Cuddapah series are each overlaid by the oldest fossiliferous rocks of Peninsular India, namely, the Talchirs, which are supposed to be of upper palæozoic age; hence the Cuddapah series must be very low palæozoic rocks, if not much older. In our Indian classification, the CUDDAPAHS, GWALIORS of Central India, and the KALADGIS of the interior Deccan, are provisionally ranged together as upper transition rocks.

Distribution.

In this region the rocks of the series are either quartzites or clay-slates, the former being the more prevalent, and giving the grand cliffs and scarps so characteristic of the above hill ranges. Kambák Droog may be said to consist almost entirely of quartzites, though in its southern portion its base is of gneiss, capped, however, by a good thickness of quartzite sandstones and conglomerates. The Kálahásti range, though mainly of thick beds of quartzites, still shows many bands of coarse clay-slates. The Veligondas, up to Venkatagiri, consist of some very decided and thick beds of clay-slates among still preponderating quartzites, the range of hills being thus broken up into many long valleys and some conspicuous ridges and outstanding cliffy masses, such as Venkatagiri Droog and Koyamon Konda. The strike of these beds runs north-north-west, and, as the range of hills bends more northerly, these with their eastward dip gradually become hidden under, or are succeeded by, the further higher groups of

quartzites in the rest of the Veligonda range. From Rápúr northwards, the range runs with the strike of the beds, and is almost entirely made up of tremendous thicknesses of quartzite strata, giving the more regular vertically furrowed wall of this part of the mountains of which Penchalakonda is one of the highest points. To the north of the Pennér the Veligondas are still mainly of quartzite strata, but with many bands of slaty beds.

Relation to the gneiss.

Except in the case of the southern end of the Kambák Droog, these masses of transition strata, however lofty they may be, are always cut or denuded down to the average level of the gneiss floor, but to the north of the Pennér, as in the Udayagiri Yerakonda and Dargadevi Konda, the quartzites are capping the gneiss either at a lofty elevation (3,000 feet), or on the long slope of the hills, and so forming a back on the gneiss mass. In fact, for this part of the field at least, there are, in these hills, unmistakable bottom beds at fully 2,000 feet above the level of the junction of the gneiss and sub-metamorphic rocks a few miles to the westward. The Udayagiri outlier is the only perfectly natural one in the district, lying, as it does, with clean cut cliffy edges, on a denuded floor of gneiss; and the Kambák Droog is the next most perfect. In all other cases the boundaries of the transition rocks are ill-defined with the strata dipping at high angles or faulted against the adjacent rocks.

Obscure members of the series.

So far there is no doubt as to the rocks being of the Cuddapah formation, and their lie presents little difficulty to the observer, but other patches and outlying strips of quartzites are met with, which are so altered in their character and appearance, and so placed in relation to the older crystallines, or so unusually situated themselves, as to have rendered the ranging of them in their proper series a matter of considerable perplexity and difficulty. These may be best considered under the headings of the Pillaméru, Kandra, and Gelacapád-Káluváya areas, and also in this order starting from the Kambák and Kálahásti ranges, from which the first is only separated by a short interval of river deposits.

In Kambák Droog the lie of the strata is in accordance with its

plateau-form, the dip being inward from the edges of the range, though there is much undulation in places. The rocks are more generally grey and buff thick-bedded compact quartzite sandstones and conglomerates. In the Kála-hásti ridge and the neighbouring Batanaik Konda the lie of the strata is not so easy, the undulations in the latter being intensified to the north until there are fair indications of a squeezed and then faulted arrangement of the beds at Kálahásti, where in the small hill (250 feet high) to the north of the town, false bedded altered conglomerates and sandstones are faulted against the gneiss. To the north of this hill no rock is seen for some 7 miles until the north bank of the Swarnamukhi is reached, when there crops up a narrow somewhat curved strip of quartzites which I cannot but look on as a wedged-in outlier of the Cuddapahs. It is to be noted that the river is here diverted from its ordinary course in a decided north and south run of nearly 8 miles in length, which may be attributed to the existence of a now-denuded and hidden prolongation of the hard quartzites of Káláhásti, or to a line of fracture in this direction.

In the neighbourhood of Kálahásti.

This outcrop, or the Pillaméru strip of quartzites, forms only a very low ridgy rise of rocky ground, much strewn on its slopes with its own debris, and around which no exact boundary could be drawn. It is not a continuous outcrop, though it appears to be so owing to covering soil and lateritic breccias and conglomerates, and I am inclined to consider that it is really broken, as it follows a more or less angular line not always parallel with the strike of the adjacent gneiss. The two northern outcrops run with this strike, while the southern ones are rather across it. A set of trap dykes on the western side also seems to point to a fractured lie: that striking in a north-easterly direction from Sheearum would, if it be continued, cut across and between the two southern ridges; a second, to the south-east of Carsearum, runs at the northern end of the proper Pillaméru ridge; and a third to the north strikes at the middle outcrop.

The Pillaméru out-crop.

These quartzites cannot be ranged with those of the gneiss series; they are undoubted sandstones and conglomerates, and are in every way like

the beds of the Cuddapah formation. They are, however, much altered and squeezed, being cleaved and jointed into crude slates and flags often having a rudely fibrous structure resembling that of fossil wood, while the pebbles and shingle of the conglomerates are apparently elongated in the direction of the strike.

This strip is evidently isolated among the gneisses and lying with them for part of the outcrop, besides being in line with the Kálahásti beds. This position and their crushed-up character would therefore appear to point to their being simply a wedged-in extremity of one of the folds of the Kálahásti beds, and thus of the Cuddapah series. Indeed, it would scarcely appear necessary to enter on any discussion of the relations of these Pillaméru beds, so evidently are they, on the face of the country, a portion of the Kálahásti strata, were it not that they are possibly allied to the more peculiarly-situated rocks of the next area.

The Kandra area.

About 10 miles east-north-east of Pillaméru, isolated masses of quartzite sandstones and conglomerates occur in most abnormal positions in and on a great outburst of trap rocks forming the group of low hills near the village of Kandra. The following notes will show the extraordinarily confused association of strata, and further details will be found in the chapter on igneous rocks.

On one of the low hills to the west of Chillamancheu there is a fragmental mass of quartzites, evidently of the Cuddapah series, consisting of blue and grey conglomerates and breccias, the pebbles of which are all of quartz. On the north side of the outcrop the beds have been much squeezed, the longer axes of the pebbles being with the strata. The main mass of the hill is of massive trap without any definite form or lie. The outcrop of quartzites is a broken curve on the top of the conical hill, giving rather the appearance of the lip of a crater, but the strike of the beds is not with the curve. The beds are dipping west-north-west into the trap, those on the top of the eastern slope at 10° or so, and those on the western side at about 50°. This curious curved fragment of Cuddapahs presents the appearance of lying on and being sunk into the trap,

as though the mass had been torn up by and floated on the igneous rock. It is not a remnant of deposition on the trap, though it at first sight looks like this, but is cut off across the strike by the intruded rock.

Buff and blue waxy quartzites occur again in and on the long ridge to the west-north-west of Bonagudapolliam, striking north-north-west and dipping vertically into the trap of the south-west side of the ridge. The main backbone of the ridge is of these quartzites, but they are crossed by very large trap dykes in west-by-north or west-north-west directions. The south-west end of the ridge is nearly altogether of compact, occasionally flaggy, buff and grey waxy quartzites striking west-by-north or west-north-west with a dip of 70° or 80° southwards, lying on a great mass of trap below which are hornblendic and quartzose schists of the gneiss series striking north-north-west and dipping irregularly.

The southern end of the low ridge due east of Kandra is of massive trap, twisted beds of quartzite similar to those of Chillamanchen being on its north side. In passing from the trap to the quartzites I crossed a heterogeneous mass of outcrops of hornblendic schists (or schistose trap) and quartzites without any appearance of parallelism between them. The idea given is rather that of broken outcrops of the quartzites with the intermediate gaps filled in by a schistose trap rock.

A low ridge lying between Kandra and Thimmasamúdrum is partly made up of coarse grey quartzites traversed by or lying among dykes of massive compact trap, but the relations of the rocks is much obscured by the enormous amount of quartzite debris, for which reason also the direction of the dykes cannot be made out. The false-bedded quartzite sandstones are contorted, but have a general east-west strike. At the eastern end of the ridge about north-north-west of Kandra the beds are wholly cut off by a great dyke of aphanite running west-by-south to east-by-north.

The southern end of the Kanakandroyan ridge, consisting of two detached hills, is a great mass or plexus of trap dykes, with an east-west band of vertical quartzite strata. The smaller hill south-west of Condagúnta is part of a great dyke, having on its south side a broadish band

of false-bedded quartzites striking east-west. Quartzites are lying on the top of the ridge in among the trap. At the eastern end of the ridge, about due west of Thimmasamúdrum tank, trap shows all round the abrupt slope, the quartzites being distinctly situated on the top. Further down the slope, however, there is a wide spread of greenstone, jointed in lozenges, north-west to south-east, and north-east to south-west, enclosing or embracing, as it were, bands of quartzite which appear burnt into the igneous rock.

Mr. Oldham writes of this region:—"The hill of Kanakandroyan consists almost exclusively of trap, hard close-grained, rather amorphous, having much the appearance of being bedded, striking north-west to south-east and dipping generally at a very low angle to south-west, with a tendency to break up pentagonally. Along the ridge, a little quartzite is seen, nearly continuous, only the highest point being free from it. It caps the ridge, apparently lying on the trap which in some large pieces may be seen united to it, the trap below and the quartzite above, both somewhat altered, the trap being close to the contact, more earthy, and the quartzite more flinty."

Proceeding northwards from this last ridge across the valley of the Venkatagiri river, trap ridges are again met with on which are two further long strips of Cuddapah quartzites.

In all these cases the quartzites are intimately associated with the basic igneous rocks and entirely separated from any gneiss. The resemblance to strata of the Cuddapah transitions is perfect, while they are not like any quartzites of the crystallines. In the latter, it is true, the approach to ordinary compact and waxy beds of the newer series is very close, but there are no such distinct conglomerates, and fair obliquely laminated beds are rare. The difficulty was to account for the present beds being in such unusual position, and the only conclusion we could come to at the time of our survey was that they are the remains of an outlying strip or portion of a compound anticlinal which formerly extended in this direction from the area next to be noticed, that of Gelacapad and

Remnants of a fold involved among and associated with traps.

Káluváya, and which possibly may have been connected with the Kála-básti and Kambák masses. The lie of the Cuddapahs in their proper field is after all in a series of sharp undulations, so strong at times as to be foldings and even reduplications, having a north-north-west to south-south-east strike, the maximum of crushing being in and to the westward of the Veligonda range. The thickness, too, in this range, along its abrupt eastern boundary, is so great that the series must, prior to the faulting, have extended much further to the east, still perhaps in undulations which might thus give faulted or squeezed-in strips of strata among the crystallines, such as that of Pillaméru, or even broken and disrupted portions of such strips in association with a violent igneous outburst like that of Kándra.

The noticeable feature, however, about the Kándra outcrops is that if they are disrupted, it is strange that none of the fundamental rocks are found in contact with them. In all cases the masses of quartzite are in contact only with trap. The conclusion is that these quartzites were deposited directly on the igneous rocks; or, preferably, that they are disassociated from the gneiss floor, and from each other in some cases, by contemporaneous or extravasated flows.

No cases of association with gneiss.

A remarkable feature of this and the Pillaméru outlier is, that they end abruptly, the latter to the north and this to the south, their extremities being in a line parallel with the direction of some of the strong trap dykes in their immediate neighbourhood. I could not, however, carry such a line into the gneiss on either side, the different bands of the latter being continued on in the country between Pillaméru and Kandra, though these bands do appear to be broken in the Swarnamukhi valley on a line having somewhat the same direction. The northern end of the Pillaméru ridge may be cut off merely by faulting, along the strike, running up from Kálahásti. The Kándra area, however, has an abrupt end of some 3 miles in width, which is hardly explainable, except by some disturbance across the line of strike of the crystallines.

Faulted to some extent.

The southern extremity of the main area of the Cuddapahs, in the Veligondas, is distinctly faulted, the intensity of the displacement having increased eastwards from Kirkambádi, while the upthrow to the south is shown in the Kálahásti hills Batanaik Konda and Kambák Droog in the present area, and Naggery Nose Nagwaram hill and others in the Madras area, most of which have scarped cappings of bottom quartzites looking to the south, at elevations of over 1,000 feet. The true direction of this Kirkambádi line or lines of disturbance could not, however, be ascertained; all that could be determined being that the throw ranged more or less east and west, if anything rather to the north of east, that is, very much in line with the northern end of the Kálahásti ridge and the course of the river. Hence it is possible that minor disturbances in the same direction, with others along the strike of the strata, combined with the extraordinary outburst of igneous rocks, were instrumental in bringing about the untoward position of these outliers and the highly altered condition of their rocks.

Southern end of Cuddapah field faulted.

Following these Kándra ridges of trap and hornblendic rocks by Potagúnta, a broken line of quartzite outcrops leads on to the Gelacapad-Káluváya area, which differs from that of Kándra in the associated igneous rocks, being dykes and interbedded intrusions instead of generally indefinable masses. Quartzites are still prevalent, but there are now some clay-slates, and the whole are much more highly altered, often to such an extent that they are hardly distinguishable from beds of the schistose gneiss.

Gelacapad-Káluváya area.

The Gelacapad portion of the area is an irregular group of quartzite hills in three arms stretching from the village, west to Bodanapali, south-east to Ráspolliam, and northward past Túmoy. Smaller ridges rise up on either side among schistose gneisses, but the bay to the south between Ráspolliam and Bodanapali is of trappoid rocks, apparently bedded north-by-west with an eastward dip, among pasty-looking syenitoid gneiss.

It was utterly impossible in such a jungle-covered country as this is to make out clearly how the quartzites are lying with regard to the

schists and traps alongside of them, but they are certainly not seen to lie naturally on the gneisses from and at which they are dipping as it were along lines of faulting, though the general outlines of the boundaries seem to be curved. The southern end is cut off in great part by the east-north-east line of fault striking out from the Veligondas at Rápúr. To the west of the patch the hornblendic schistose rocks of the plain and the small ridges of quartzites are much traversed by west-by-north to east-by-south dykes of greenstone, and the main ridge itself is underlaid in part and cut by the same rock. The east side is again bordered, with an interval of granitoid and schistose rocks, by a strong ridge of quartzite breccias and conglomerates towards Govindapully, beyond which are schistose gneisses with many intercalated small flows of trap and bands of quartz-schist hardly to be distinguished from Cuddapah quartzite. These quartz-schists are, however, essentially micaceous, and are much charged with epidote in little separate assemblages of crystals, or in minute particles when the rock is of a green colour. These quartzites are dipping at various angles to the eastward, and strike with the curve of the two southern ridges, making a bifurcation round the bay of gneiss and traps to the south.

Relation to the gneiss.

The Túmoy arm is not continued across the Tummalatulapúru stream, but the smaller quartzite ridges to the west of it are traceable northwards very nearly to the next strong outcrop of transition beds extending as a narrow curved ridge from Paremkonda to Káluváya, while these smaller ridges and the southern end of the Paremkonda ridge are flanked on the western side by a strong band of gneiss and granitoid rock. The smaller ridges are, however, in many cases so doubtfully either of crystallines or transition strata, that I have thought it best to rank them as of the former series, thus leaving a gap between the Gelacapad and Paremkonda outcrops.

From the latter place to Káluváya the outcrop is very decided, the beds of the ridge being good quartzite sandstones and conglomerates of unmistakable Cuddapah facies, lying with an eastward dip against

schists and granitoid rocks which are also dipping eastward on their seaward edge. To all appearance, this ridge might be one of a set of quartzites in the schistose gneisses were it not that I think there is some sign of general unconformity of the beds on the schists to the westward, and that the schists on the eastern side do not follow the regular and marked curve of the ridge beds. It will also be seen directly how, in the prolongation of these beds beyond the Pennér, good evidence of unconformity was noted by Charles Oldham.

Appearance of unconformity with the gneiss.

There must be a curved line of fault running along the eastern edge of this ridge, though all direct evidence of such is concealed beneath superficial deposits. The crushed-up curve in the middle of the ridge length, the altered condition of the beds themselves, the enormous quantity of quartz collected in lamination and cleavage fissures all over and in the neighbourhood of the ridge, are all points in favour of this view.

Faulted eastern boundary.

About the middle length of the ridge, where there is a sharp bend in the strike of the beds, the quartzites are compact flint-like and much traversed by strings of white quartz silvered with mica and talc. The lower beds forming the back of the ridge are coarser; and with them are some thin outcrops of trap. Further north towards the great tank, flint-like or jaspideous green quartzites are frequent, and the intrusive traps are tremendously developed in a main sheet cropping up down the valley between the now widened and double ridge and in two other smaller ones. These extravasated traps continue northwards to the Pennér, but not always between the same beds, for, though I could never find them breaking through, they disappear and re-appear above or below well-marked outcrops, the large one of the valley appearing to have passed up over the highest quartzites as it is seen under the village of Káluváya, which is outside or to the eastward of the quartzite outcrops. At the same time, there are many similar outcrops running with the schists on the eastern side of the ridge. Some of the

Crushing and alteration.

Trap flows, intrusive.

quartzites associated with the traps in the ridge are epidotiferous, but these are not necessarily in contact with the trap.

The Káluváya ridge well separated from the Veligonda beds.

In the field, and for long after the survey, I was much inclined to consider that the rocks between the northern half of the Káluváya ridge and the Veligondas were also of the same series, but on a thorough review of all my notes, I am compelled to give this point up and accept the suggestion often urged by Charles Oldham that the gneiss series is really continued in this direction. The rocks are certainly more schists than slates, the latter being essentially characteristic of the Cuddapah clayey strata, and they are associated with hornblende schists which must be considered, in this field at any rate, as belonging to the gneiss series. The most important point, however, is, that while the Káluváya ridges are continued on the north bank of the Pennér, the apparent Cuddapah facies of the rocks between Káluváya and the Veligondas is not at all so marked in that direction.

At the same time I do not put forward the boundaries of this part of the field as hard and fast lines, for there is no doubt that many thin and long outcrops of compact waxy quartzites and even some conglomerates do occur alongside the Gelacapud and Káluváya areas, which I could not but look on as true Cuddapah strata, and which, if so settled, would narrow the belt of gneiss between the Veligondas and the outlying ridge of transitions very considerably.

Continuation of the outcrop across the Pennér, unconformable on the gneiss.

On the north bank of the Pennér, the low ridge of Varagúntapad is of Cuddapah quartzites, which are carried on to and form the long eastward-sloping back of the Bommavaram hill or Dargadevi Konda, whence they are continued, with intervals of plain and covered-up ground, in the Yerakonda ridges.

These beds are now beginning to cap the hills, giving grand scarps on nearly all sides, but particularly to the westward, and they are more evidently unconformable on the schists. At the same time, the eastern boundary, which is probably a faulted one, is hidden under the talus of

debris on this side of the hills. Their strike now trends in to the Veligondas, from which, however, they must be cut off by faults, there being no outcrop of bottom beds corresponding to them in the range. The Udayagiri plateau may be a portion of the same band, but even so, it is detached from it by a wide interval and by tremendous displacements, being, as it is, a denuded cap of nearly flat strata at an elevation of about 2,500 feet over the level of any quartzite boundary to the south or west.

Mr. Oldham wrote of these ridges and hills north of the Pennér, and some of his notes are particularly interesting as giving instances of unconformity of the quartzites on the gneiss, even in the Dargadevi Kouda, the rocks of which are undoubtedly continued in the Káluváya ridge. He also shows that these qnartzites are overlying not only the schistose gneiss, but that they extended on to the massive gneiss, a narrow strip of which crops out here.

The Cuddapahs in the Veligonda range.

The Veligondas themselves consist for the most part of quartzites (conglomerates and sandstones of all kinds and colours) in great thicknesses associated with fewer and thinner bands of clay-slates, micaceous and talcose slates, and still fewer schistose beds, all of which are dipping generally to the eastward, but with many undulations and some reduplication. The eastern edge of the range is fringed for the greater part of its length by a talus of debris

Faulted against the gneiss.

of good width, which conceals the main eastern boundary of the Cuddapah formation, though the newer and older rocks are at times traceable to within very close proximity. In all such cases, however, the indications are that the boundary must be an abrupt one and faulted to a great extent. The beds dip constantly at high angles at the gneiss and have a crushed appearance, and the serial order of the rock groups seems to justify the conclusion that there must be great thicknesses of quartzites and slates faulted immediately west of and below the level of the adjacent gneiss.

The boundaries striking westward and northward from Yárapet, at the southern end of the range, are certainly faulted, the downthrow inside these lines being at least 1,000 feet at the village, whence it decreased

westwards towards Kirkambádi. The great eastward break must run north-north-west from Yárapet to about the parallel of Kossi Konda, when it turns more northerly and continues still faulted, for it is running at a good angle across the well-marked strike of the beds to the parallel of Nagwaram hill. Hence, but now with the strike, there must still be a faulted line running north-by-west to the parallel of Rápúr, there being too narrow a space between the quartzites and the gneiss to allow of any sudden thinning out of such a thick series of rocks as is displayed in the sections to the westward. At Rápúr there is a wide and very abrupt abutment of the ends of the transition strata against the gneiss at right angles to the more general lines of fracture, on either side of which the older and newer series approach very closely. From the same town, the boundary again runs north-north-west, but not always with the straightness assumed to be peculiar to a faulted edge, up to the Pennér. Northwards from this river, the boundary is more curved, the gneiss and quartzites still, however, running so close that a natural boundary seems out of the question, and this is only more clearly indicated by the features already described in the account of the outliers to the east of this part of the range.

The rocks of the Veligondas.

The rocks of the Veligondas have been described in the memoir on the Cuddapah formation, and as they are of little interest petrologically, being merely recurring and succeeding, from south to north, bands of quartzites and slates, it would be mere repetition to refer at greater length to them in this paper than has been already done. The quartzites are everywhere seen to be true sedimentary beds, great spreads of rippled sandstones being frequent all over this range, and their sandstone or conglomeratic character, if not seen at once, as is often the case in the wonderfully compact and dense rocks, is soon evident where they are weathered. The clayey beds, on the other hand, have assumed more of a schistose character than is usual in the rest of the Cuddapah area, strong bands of rusty-brown and dark-green talcose and chloritic schists being common in the portion of the range south of Rápúr, which are traceable to the westward into easy-

lying clay-slates; and their altered condition is plainly attributable to the great crushing and folding displayed in nearly every cross gully or gorge in the mountain wall.

C. Æ. Oldham's notes on the rocks north of the Pennér.

Throughout this description of the metamorphic and sub-metamorphic rocks, I have availed myself largely of the notes and field maps of the late Charles Oldham, referring to the southern half of the field; but as I myself only touched very slightly on the country north of the Pennér, I think it best to give his remarks on that area in *extenso*:—

"The rocks to be noticed are throughout of the metamorphic class, with exceptions to be noticed hereafter, and may be generally described as alternating bands of hornblende schists, micaceous talcose schists, gneiss (proper), and quartz-rocks—an intensely quartzose gneiss. This quartz-rock forms a very marked feature of the country—many, indeed the great majority of the small ridges and hills, consisting largely or exclusively of it—owing, doubtless, to its great hardness and consequent power of resisting denudation and atmospheric action.

"There are, however, as noticed hereafter, some instances near the ghâts of a quartz-rock of another series, overlying and unconformably overlying these older metamorphic rocks.

"In going across the country westward from the coast to the line of the ghâts, we first rise from the alluvial deposits and sands over a scarped ridge of laterite nearly continuous from the river to the north of the sheet, and descending on the west, frequently over well-marked scarps and bluffs of 20 to 40 feet, find ourselves in the region of metamorphic rocks, which extend thence in uninterrupted succession to the ghâts in a series of rolling beds.

"Locally granite and quartz veins are numerous, but small. There is considerable variety in these metamorphic rocks. Typical gneiss, of compact substance, is comparatively poorly represented, though it occurs in several places, and is in some of these largely quarried for building purposes, as, for instance, near Boochareddypalliam (a large village about 12 miles north-west of Nellore), where on the north of the village a close-grained compact granitoid gneiss occurs in considerable quantities,

and has been worked extensively for buildings, both in the immediate neighbourhood and at some distance. I believe almost all the materials of the new pagoda at Nellore were quarried here. Much further west also, near the ghâts in the neighbourhood of Bijjampalle, there is a considerable extent of granitoid gneiss (well adapted for building stone) forming hills of some size. Here, however, and also further south near Govindapully, where it also occurs, but in smaller quantity, it has been but little utilised.

"More schistose varieties of the gneissic rocks are much more largely developed, and hornblende schists, mica schists, and talcose schists form the greatly preponderating portion of the rocks of this part of the district, garnetiferous hornblende schists being largely abundant. From these, however, I did not succeed in obtaining any crystals of garnets at all so good as some from the more southerly parts of the district, *e.g.*, near Chittaloor, Thooroomulla, &c., from which places we procured numerous excellent crystals of various sizes from 1 inch and more in diameter to ⅛ inch. In the north-western parts of the area under notice micaceous and talcose schists prevail largely, frequently much contorted and often very slaty and earthy in character, and sometimes closely resembling some talcose slates in the 'Cuddapah series.' Indeed, in places the resemblance is so great that hand specimens of each could rarely be distinguished one from the other, and in some cases, where the more slaty beds of this Cuddapah series overlie these similar beds of the older metamorphic rocks, it becomes difficult to fix the line of boundary between them, specially when, as is sometimes the case, the strike is almost or quite identical, and owing to the contortions (of the lowest beds specially) the dip becomes so locally; and the similarity is great, not only between the talcose schists or slates of either series, but also between the quartz-rock or intensely quartzose gneiss of the one or the quartzite of the other. A case in point occurs in the hill east of Bomaram (Bommaveram), the lower part of which consists of hornblende schists, gneiss, and quartz-rock in alternating bands, striking about north-north-west and having a general dip to east-north-east at various angles, the beds rolling much, while the hill is capped by quartzite of the Cuddapah

series with nearly or quite the same strike and in some parts almost coincident in dip. And it is only by observing that in parts of the hill these Cuddapah rocks overlie the metamorphic series at a very different angle, that their general unconformability can be satisfactorily established.

"A somewhat similar case is seen in Oodagherry (Udayagiri) hill further north, where the low dip of the beds of quartzite which cap the hill, sometimes almost exactly coincides with that of the rolling contorted beds of talcose and micaceous schists and slates, which form the mass of the hill, while this quartzite, although as I think generally, even in small specimens, distinguishable, frequently so closely resembles quartz-rock occurring in bands in the lower metamorphic rocks, that it renders the distinction between the two at first sight difficult and doubtful.

"Generally, however, as above noticed, the quartz-rock of the lower series, or metamorphic rocks proper, contains minute grains or scales of mica, which in some specimens are very clearly seen and appear to form extremely thin layers in the rock (sometimes well seen on a slightly weather-worn surface), but in other specimens are so minute as to be hardly observable.

"Here also, as in the other instance cited near Bomaram, though apparent conformability exists locally, the general unconformability is tolerably distinct. In both these cases, the capping quartzites form a fine precipitous scarp, which in Oodagherry hill is of about 200 feet in height, and almost vertical and wall-like. In Bomaram hill there is a much greater thickness of these beds, probably 400 feet, appearing on the southern face of the hill, and forming a remarkably fine precipitous bluff, a most conspicuous object as the traveller approaches from the westward.

"In smaller hills north-east of Chunchulur I found a thin capping of quartzite lying over micaceous and hornblendic schists, the strike of both locally exactly the same; the upper beds dipping at lower angles and in places the schists underneath vertical.

"In a small ridge south of Govindapully, nearly due west of Mustafapuram, I note micaceous and quartzo-micaceous schists dipping at 70° to 75° to east-by-north, capped by quartzites which dip in the same

direction, but at much lower angles (25° to 30°). The lowest bed of these quartzites is here a coarse conglomerate, containing numerous pebbles of quartz of considerable size, 6 inches and more in length, of a flattened oval form, the longer axis always being in the direction of the strike of the beds. Above this is a hard grey quartzite, and locally, lying rather in broken disconnected patches, not forming any continuous bed, are some pieces of slates very like some of those occurring in the 'Cuddapah series.'

"Proceeding further north, outside the line of the Ghâts, a low ridge extends from south-east to north of the village of Chabolu, composed of quartzites capping the schistose beds. Close to Chabolu are seen quartzo-felspathic gneiss and micaceous and talcose schists and some hornblende schists, striking north 5° to 15° west, twisted and rolling, but dipping generally at a rather high angle to east 10° to 15° north. The quartzites above dip at lower angles, but in the same general direction. The lowest bed is a conglomerate, a siliceous and siliceo-talcose matrix, including pebbles of quartz of considerable size. I have noted this bed as very similar to that seen near Govindapully, but the unconformability not so well marked. The ridge stretches almost exactly in the direction of the strike.

"There is also a thin capping of quartzite, partly conglomeratic, seen lying on the small hills north-west of Kothapulla and south of Annumpulla. Here there is very little seen, only a few feet covering the top and eastern slopes of the hill. The rock beneath here is a rather massive typical gneiss.

"As regards the character of the metamorphic rocks generally in this part of our area, there is little to be said of much interest or novelty. As remarked above, typical massive gneiss is but feebly represented. A band of some considerable breadth, generally massive and granitoid, with indistinct bedding or lamination, extends along the east of the Ghâts from the Pennér to the northern edge of the sheet, with a breadth of 2 or 3 and even 4 miles, varying somewhat in character. In the southern portion of this, near Govindapully, &c., hornblendic and mica-

ceous bands occasionally appear, but the mass of the gneiss is much less schistose and more massive, and has much more the character of typical gneiss than the rocks further east, and it is almost entirely without the numerous bands of quartz-rock which form so marked a feature throughout the remainder of this north-east quarter of the sheet. The northern portion of this band is even more massive and granitoid, and from west of Beejumpulla to near the north edge of the sheet there are from 3 to 4 miles in breadth of a very massive granitoid gneiss, forming hills of considerable size, the lamination or bedding of which is frequently very indistinct, and indeed, except in the mass, or where considerable surfaces are exposed, often not recognisable at all. It is not, however, very largely or markedly crystalline. It is almost entirely devoid of schistose beds. Only in one or two places did I notice some micaceous schistose bands in it.

"In several other places, indeed almost everywhere throughout this area, occasional, but generally very narrow bands of more typical gneiss, alternate with the hornblendic and micaceous schists and quartz-rock which form the main portion of the rocks, but none of them are of sufficient importance to require special notice.

"The remainder of this portion of the sheet (north-east quarter) is made up of a series of alternating bands of hornblendic, mica, and talcose schists, and quartz-rock. The bands of the last-mentioned, as above observed, form a very marked feature throughout this part of the country. A large proportion of the small ridges and hills which vary the otherwise rather monotonous level ground consist either principally or exclusively of this rock, which is a highly crystalline quartz-rock, commonly grey or whitish in colour, but often weathering somewhat brown or reddish. It bears a very close resemblance to many of the very hard and crystalline quartzites of the Cuddapah series, perhaps more specially to some of the bands capping the hills along the Eastern Ghâts, *e.g.*, in the Budvail Taluq. It may, however, be generally distinguished from these by some characteristic peculiarities. The presence of minute scales of mica can generally be detected, although they readily escape notice, and are commonly clearly seen only on the surfaces of the laminæ or thinner beds.

The surfaces moreover, though frequently well exposed in large flat sheets, are never, as far as my observations go, ripple marked, whereas the presence of ripple marks is extremely common in the hard quartzites of the Cuddapah series. This quartz-rock is seen alternating in beds of very various thickness, with the hornblendic and micaceous schists. The bands are sometimes only an inch or two in thickness, and very numerous within short spaces, but frequently they are of very much greater thickness, and form ridges of no inconsiderable size.

"These bands of quartz-rock with a similar character occur also abundantly south of the Pennér, and there also form ridges as here, but they appear to increase in frequency north of the river, and spread out northwards in a fan-like manner, with their alternating schistose bands from about 20 miles south of the Pennér to the northern edge of the sheet. The general strike of the beds is about north-north-west, varying, however, considerably, trending more to north-west in the westerly parts of this quarter-sheet, and approaching more nearly to a north-south strike in the eastern parts. The quartzose bands are somewhat less numerous in the western portions, which consist more largely of micaceous and talcose schists, with some hornblendic and quartzo-hornblendic bands, and a few narrow bands of quartzo-micaceous and quartzo-felspathic gneiss.

"Talcose bands occur also apparently continuous with some of these south of the Pennér, where I noticed them in the neighbourhood of Navoor, Yatoor, and north-west of Saidapuram, where near Jogipali, a highly talcose gneiss or talc-rock is quarried to a small extent and worked into small pots, figures, &c.

"In many bands, chiefly of hornblendic and quartzo-hornblendic schists, garnets are largely abundant, specially so in a series of hornblendic schists extending in a north-north-west direction by Jummawdrum, Kotapela near Kanigiri, Woopaloor, &c. A similar (probably the same) band of rocks continues south of the river near Ayergarpilly, Lingumpully, Thooroomulla, and near the last-named place we procured many excellent crystals, very perfect and of various sizes, from more than

an inch in diameter to less than ⅛th of an inch. I noticed in one or two places in quartzo-micaceous schists, mica appearing to replace garnets, having at least assumed their crystalline form."

CHAPTER V.—GRANITIC AND TRAPPEAN ROCKS.

The massive metamorphic rocks of the Kálahásti and Venkatagiri regions are only slightly marked by seams of hard binary granite of pink and white felspar and dull grey quartz running with and across the foliation; but the gneiss is so frequently granitoid itself, that it is difficult to decide whether these are really intrusive or that they are mere segregations.

The Ogili and Gúdúr granite.

The most noticeable development of granite is, however, among the foliated gneisses, and here again the reefs are nearly always running with the foliation, so that they must, if they are igneous, be considered extravasated veins, though they also appeared to me to be the result of segregation. These occur on or alongside the main northern road between Ogili and Gúdúr as a very crowded system[1] running generally in a north-north-west to south-south-east direction among hornblendic, micaceous, and quartzose schists. From Gúdúr northwards granite is frequent at intervals all along this belt of gneiss right up to the northern edge of the field. The rock is mainly a very coarse binary aggregate of quartz and felspar (orthoclase), the ordinary ternary form with mica (muscovite) being, however, frequent at places.

At the Calingula or weir of the Karevádu tank, the micaceous and hornblendic gneiss is intruded on by veins, 3 or 4 feet wide, of coarsely crystallized granite which run between the beds and along the east-west joints. The rock in this neighbourhood is of flesh-coloured

[1] I found it difficult to represent the reefs of Gúdúr granite on the map as they are so numerous and yet not large enough to allow of their being separately mapped on the 4-inch scale. I have therefore delineated bands in one colour, which are to be considered as areas of stronger development. In the same way I have represented areas of trappean outburst in one colour, though the real condition of things is often a confused plexus of dykes and trap masses among hornblende schists.

felspar bluish-white quartz and light-brown silvery mica, largely crystallised and charged with garnets. It often assumes the form of graphic granite. The granite veins do not often contain garnets, or indeed any foreign minerals, but the association with garnetiferous schists is remarkable. In one instance about a mile and half east of Turamulla (on the southern tributary of the Kándléru) there is a string of tourmaline and garnet crystals occurring in one of the larger granite reefs, the garnets of the adjacent schists being large and perfect dodecahedrons. Every now and then along the road from Ogili to Gúdúr there are frequent outcrops of this granite, the road metal having been obtained from decomposed masses on either side, and sometimes the mica is so strong that the road and the adjacent fields shine out in the sun light. At the junction of the Madras and Dugarazupatam roads, the plates of mica are 3 or 4 inches in diameter.

Trappean rocks in definite and ill-defined outbursts.

The commonest igneous rocks in the district are greenstones or diorites, which are, however, more particularly developed in the Kándra and Gelacapád areas already specialised on account of their quartzite outcrops.

These trap rocks may be very conveniently classified in the present connection as definite and ill-defined outbursts; the former being, of course, the well-marked dykes and intrusive sheets, while the latter are irregular masses of obscure origin, often presenting the characteristics of both dykes and sheets, but of great extent as compared with the true and obvious igneous intrusions.

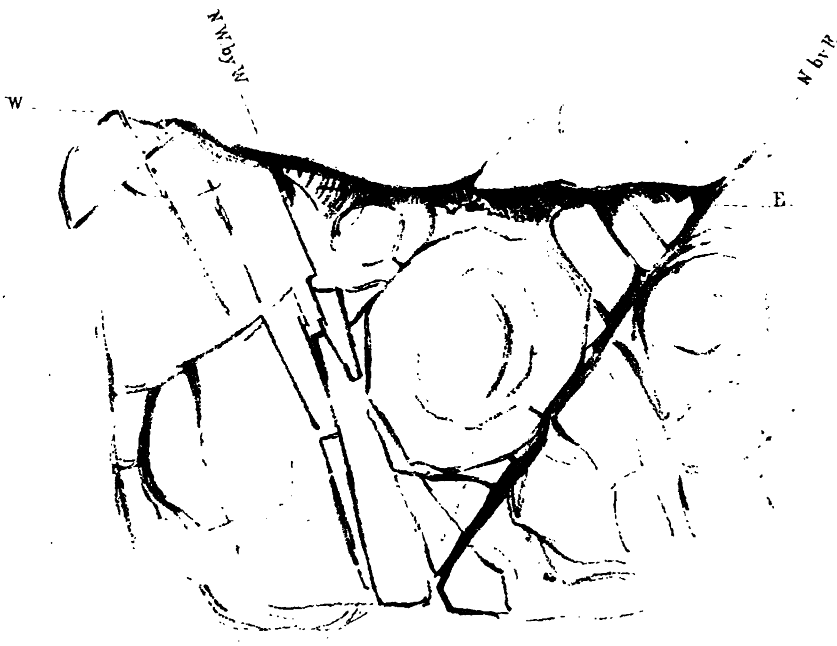
Dykes in the gneiss.

A few large dykes occur in the south-west corner of the field, which are the dyings-out of a tremendous development in the South Arcot country. They are striking either west-by-south to east-by-north, or about east-west, and others run north-west or again nearly with the general strike of the foliation. The rock is usually a heavy massive somewhat coarse-granular diorite of dark-green or nearly black colours, and it is occasionally porphyritic with large crystals of pale-green felspar. In the Swarnamukhi valley, to the east-south-east of Kirkumbádi fort, there is a large west-by-south to east-by-

north dyke of compact porphyritic greenstone, with numerous separate crystals of yellowish-green felspar. Many traces of dykes occur in this neighbourhood, some of which are evidently porphyritic at times and oftener compact and homogeneous.

Relation between spheroidal weathering and jointing.

An interesting and instructive example of the spheroidal weathering of these traps occurs in the Kirkumbadi dyke, where it crosses a stream about 4 miles east-south-east of the fort, in so far as it illustrates the important part taken by jointing in the production of these rounded forms. The trap shows apparent bedding due to a plane of jointing dipping north at 15°, and it is also cut by north-west-by-west, north-by-east, and east-west nearly vertical joints. It will be seen from the accompanying portrait, of one of the flat joint surfaces, that a prismatic



Portrait of a sloping joint-surface of a trap dyke.

mass with a triangular base has been separated by the three main joints, but that other less persistent joints, or, preferably variations of the main joints, have given the core of the prism a polygonal and finally a rudely circular base, while the nearly flat joint system with its slight variations assists in the ultimate rounding of the block.

From the Swarnamukhi northward to Rápúr the number of dykes is small, none of them being of importance as to size or length, and they are all of ordinary compact diorite; but as the latter village is approached, they become frequent and are remarkably persistent up the valley between the Veligondas and the Gelacapád-Káluváya hills. At Bodanapali, many wells, 20 to 30 feet deep, are sunk through grey schists, showing numerous small trap dykes, 3 or 4 feet wide, running in all directions and at all angles. They run with the bedding, or across it, to the north and to the east. Between Rápúr and Gelacapád, all the rocks are very igneous-looking; a grey pasty porphyritic rock, which I, however, suppose to be the same as that of the grey gneiss series towards the Swarnamukhi valley, fills up the bay between the quartzite ridges and is traversed by strong dykes of aphanite trap in a north-by-west direction with an eastward dip. Further north, and eastward of Ullapuram, the country is much intersected by trap dykes striking east-north-east, the rock being often a dense black aphanite. The low hill north-east of Pocrapali is a perfect network of dykes, as is also the ridge to the south.

The cross dykes are also associated with the transition rocks, for the most part obscurely, but still at times as undoubted intrusions. To the south-south-east of Túmoy, there is a large dyke at the north end of a low hill of quartzites, and this runs right at and under the ridges in an east-west direction, showing every now and then in the small valleys between, while a small branch of this dyke traverses the beds very clearly. Some of the dykes are very broad and long, that of Túmoy and another parallel one to the north being traceable for 3 to 5 miles with a breadth of 100 feet, while a third runs north-north-west past Panumurti for a length of about 7 miles, with a breadth sometimes of 150 yards.

Dykes in the transition rocks.

The Paremkonda-Káluváya ridges are also intruded on by sheets of diorite which for a good part of their length appear to be contemporaneous. However, on following them out they are seen to vary much in thickness, swelling out every now and then, while they die out and are succeeded in the strike too suddenly by other similar outcrops above and below the adjacent quartzites to be contemporaneous flows. They commence thinly in the sharp curve north-west of Paremkonda, and then rapidly increase in thickness towards and under Káluváya. It is of course difficult to recognise in generally altered strata any effects produced by such intrusions, but the quartzites in their vicinity are certainly jaspery or flinty, an uncommon condition of these beds, and they and the traps themselves are epidotiferous.

Intrusive traps of Paremkonda.

To the south of Gelacapád, there is again an unmistakable region of flows and ill-defined outbursts of basic rocks, which, though probably part and parcel of one great igneous development, is certainly disconnected from that of Paremkonda, either by an area of milder action, or, as I prefer to think, by an actual break along the Rápúr line of faulting. I have represented this southern area as continuous by the Potagúnta ridges[1] on to Kándra in the map, and there is every reason to consider that it is so in fact, but a good part of it is covered up by the superficial deposits of the Venkatagiri river.

Irregular outbursts of trap.

At first sight, the Kándra or Kana-Kondroyan hills seem to be wholly of trap, like the remains of a great protruded mass of volcanic rock; but on examination they are found to be really of massive hornblendic and chlorito-hornblendic rock, extensively traversed by dykes and irregular masses of trap, running mainly in north-west to south-east, east-west, and east-by-north to west-by-south directions, the whole occupying a wide belt thinning out

The Kándra outburst.

[1] The Potagunta ridges were examined by Charles Oldham, and he seems to have considered that they, on the whole, consisted more of massive and schistose hornblendic strata, with fewer trap dykes and dioritic masses.

to the north-west and cut off abruptly to the south-east near Chillamanchen. At the north-east end the traps have more of a bedded look, and from this point the inter-bedded or extravasated character of the outcrops becomes more evident as the Paremkonda ridges are neared. The hills immediately west of Kándra show more frequently the dyke form of intrusion, while the Chillamanchen hills are so devoid of any dyke-like development, except on their flanks, that they look more like a great mass or centre of outburst. Immediately west of the latter village, the small group of dark-coloured moderately-rounded hills consists in the main of a dense blue-black aphanitic greenstone, which weathers of a dark red-brown colour, occasionally into large rounded masses, or into an earthy rock speckled with little rounded masses of dull carbonate of lime. On the west side of the main hill there is a broad dyke striking east-by-north to west-by-south through the rest of the trap and across a narrow band of quartz-rock and talc schist, which is also in among the traps and has a north-west strike (the strike of the Cuddapah quartzites on the top of the cone is nearly north-south). Armenpadi, about 3 miles north-north-west, is a compact fine-grained blue-black aphanite, the ridge to the north-west being also composed of coarser trap weathering into great rounded masses. Kándra village is on trap which can be traced, associated with hornblendic schists, thence to Vendodu; and northwards from the latter village the path to Vadacherla passes over a series of hornblendic schists traversed by, and interbedded as it were with traps in the same way as in the Kándra valley. The schists are contorted, but strike generally north-north-west.

The dykes intersect each other both here and in the Rápúr country, but without giving any indications of different periods of intrusion: both those across and with the strike of the country rocks appeared to belong to the same outbursts.

The obscure association of the traps with the country rocks is to be seen on the western edge of the Kándra area. On the Vizinagram side, highly contorted beds of micaceous and hornblendic schists, with frequent small seams of granite and small trap dykes, border the trap mass of the hill. The strike of the schists is north-north-west with various dips,

but close on the trap the contorted beds are strong, with a west-by-south to east-by-north strike. The western side of the ridge is a great mass of east-by-south to west-by-north dykes traversing massive hornblendic talcose and chloritic rocks and micaceous schists, having a north-west to south-east strike, the traps being, however, greatly in the ascendant. The dykes are generally of a massive coarse dark-brownish-green diorite, which weathers into a coarse earthy ferruginous rock, while others again are more of an aphanite. The highest part of the ridge is entirely of massive and coarsely weathered trap, extending over many hundred square yards. Along the south side of the ridge the character and appearance of the rocks vary much. First, the trap forming the summit is a massive well-crystallized rock of a dark-grey nearly black colour of hornblende and felspar, through which run large, probably segregated, strings of dense blue-black rock. Next, the rock becomes more felspathic with the hornblende, showing in large crystals, or oftener in small assemblages of radiating needles, giving the weathered surface a starred appearance. This syenitoid character of the rock extends up to the Vendodu tank. Vendodu itself is on coarsely crystallized granitoid gneiss, perhaps rather a granite, a great band of which passes along this side of the range past Vizinagram and Armenpádu. Near these villages a band of coarse quartzo-felspathic rock, having a somewhat laminated structure, and including angular fragments of hornblendic schist, extends in a north-north-west to south-south-east direction. The rock is very coarsely crystallized and is riddled with numerous strings of quartz. To the eastward of this there is a band of massive acicular hornblendic rock, and east of this again is more granitic rock, after which come the schists with granitic strings and small trap dykes above noticed as bordering the trappean ridge. There are no cases of actual contact, the base of the hills being always covered with debris of the rocks above, or else by the soils which run close up to the traps of the hill masses.

CHAPTER VI.—OTHER FORMATIONS.

(1).—Rajmahal Plant Beds.

The merest traces of some plant shales of this series were discovered by Charles Oldham on the northern edge of this area, which he afterwards carried on into the Kistna District, where they have since been thoroughly worked out and reported on by Mr. Foote.[1] Indeed, it was after all by the merest chance that the first indications of these Rajmahal plant shales were found in the debris thrown out of some wells which had pierced the laterite and sandstone plateaus of Nellore and Kávali. I myself found pale-yellow and buff clayey and sandy shales, very similar to those of the plant-beds of the Trichinopoly district, but unfossiliferous, at three localities—Chúmurugunta, about 6 miles south-south-west of Nellore; Kálavakonda, 7 miles east-south-east of Gúdúr, and at Shengapetta, 17 miles north-north-east of Nellore, all in well-excavations. About the same time I heard from Oldham of his having found fossiliferous shales of the same kind, and thus it became evident that the Trichinopoly and Madras belt of Rajmahal rocks extended nearly all along the Carnatic. Oldham subsequently found many little patches, so small that they can only be represented very generally in the map attached to this memoir, and concerning which he furnished the following notes in 1862-63:—

Mere traces of Upper Gondwanas in this area.

"In the north-east quarter sheet, in the Kávali Taluq of the Nellore district, I have discovered and secured some specimens of plant remains from sandstones which from their similarity to, or identity with, plants discovered elsewhere, possess considerable interest.

"The sandstone and shales in which they occur are confined, as far as I could determine them within the limits of sheet 77, to a few square miles west and north-west of the town of Kávali. I have noticed them close to the villages of Timmasamúdrum, Kún Korepolliam, Ramanjapuram, Comy Mutumarpolliam, and Sodawaram. Beds of similar charac-

[1] Mem. Geol. Surv. of India, Vol. XVI, part 1.

½ mile, where I observed a coarsish ferruginous sandstone, with some fine yellowish bands, very little of them being seen, chiefly from small bowries. In some of these finer bands I found traces of plants which I considered sufficient to identify the beds as being the same as the plant bearing sandstones seen elsewhere.

"The weathered surface of a quartzo-felspathic gneiss in a small hill south of Gutergully presents such a remarkable similarity to these beds close by, that it seems hardly possible to avoid the remark that the materials of which they are formed might have been readily derived from the rock in the immediate neighbourhood.

"Lying on the sides of this small hill in large masses is an extremely coarse conglomerate, the matrix of which is not unlike some of the more ferruginous bands of the sandstones. I could not trace its connection with these sandstones. The pebbles which it contains, many of which are of considerable size (6 inches and more in diameter), are all, as far as I saw, of quartz-rock, or intensely quartzose gneiss, rounded and water-worn. Possibly it may have been a beach deposit of the plant-bed age, but though I could obtain no distinct proof, I should incline to consider it more recent.

"The only other locality remaining to be noticed is close to Peddawaram (just outside the boundary of sheet 77), north-west of Chellum of the map. South-east of the village a coarse ferruginous (lateritic) grit, in parts pebbly and almost conglomeratic, capped by laterite, form a well-marked bluff of 25 to 30 feet, trending northwards and turning round east of Nurṣapuram, in which direction and south towards Chintalpalem, it diminishes in height and ceases to be a well-marked scarp and dies out in a laterite pebbly deposit thinly spread over the metamorphic rocks. Close to Peddawaram (sheet 76), in the low ground south of the village, yellow micaceous sandstones, which I suppose to be of the plant-bearing series, are seen in a bowry, but no specimens of plant remains were procurable. I was unable to trace them into connection with the lateritic grit, which, however, from its position, must be at a higher level, and have probably overlaid the sandstones, and been here denuded, leaving the existing scarp, round the base of which all rock is

obscured by a sandy alluvial soil, in which is dug the bowry showing the sandstones.

"In pieces of ferruginous sandstones in the tank-bund of Cotapali, I found specimens of plants (*Tæniopteris* and grassy stems) but I could not trace the rock with certainty to its site. The stone, however, was said to have been brought from the north near Peddawaram, and I have little doubt that it was so, as it would be the most convenient place from which to obtain the stone."

This Peddawaram patch is referred to by Mr. Foote in his memoir[1] on the Kistna district as belonging to his Kundakur group of the Rajmahal outliers; and it is quite evident that the areas just described must be considered as belonging to the same group.

(2).—CUDDALORE SANDSTONES.

The belt of rocks belonging to this group extending along the Nellore coast is to all appearance rather one of laterite and lateritic deposits than a set of sandstones answering to those near Cuddalore and Pondicherry, to which Mr. H. F. Blanford gave the name of the group. However, in the many wells sunk in it and at certain points along the western edge, there is no doubt of the existence of similar sandstones; and as in the Tanjore, Trichinopoly, Cuddalore, and Madras areas no fair separation of the lateritic part of the outcrops from the arenaceous portion has yet been discriminated, I take it that these plateaus of the Nellore district are still essentially of Cuddalore grits, though they are undoubtedly in places overlaid by a skin of lateritic breccias and conglomerates which must be considered as belonging to comparatively recent deposits, or to Mr. Foote's group of "Lateritic deposits." At the same time it is necessary to state that I do not (nor indeed did Oldham) go with Mr. Foote altogether in his discrimination of these deposits, as will be seen on a comparison of the map of this memoir with his map of the adjacent Nellore and Kistnah area, wherein he does not show any Cuddalore sandstones at the southern edge near Ramiapatnam. We carried these rocks from the Red Hills of

Difficulty in distinguishing them from the lateritic deposits.

[1] Supra, pt. 1, p. 52.

Madras into the present area, and so followed them out up to Ramiapatnam without meeting with any good evidence to show that the group had ceased or become overlapped by another distinct group. Foote's separation of the lateritic deposits was certainly later than our survey of this part of the Nellore district; but even now, after a careful study of my notes then taken, and after having seen the further extension of these sandstones and their lateritic character in the Godavari district, I do not see any fair reason for altering our opinion regarding the northern end of the Nellore patches.

Good sections in these Cuddalore sandstones are extremely rare, the higher western edges being rounded off and covered with a ferruginous coating; indeed, this surface of the plateaus is always weathered into a lateritic or ferruginous rock for some depth, the true grits and conglomerates showing often the usual lateritic features of tubiform and cellular cavities, scabrous surfaces, and a pellety or pisolitic structure. Well-sections are generally the only ones in which an idea can be obtained of the rocks forming this part of the series.

The general character of the area is, that the patches forming the belt are essentially lateritic, with only rare exposures of grits and conglomerates up to Nellore, beyond which point the more arenaceous constitution is prevalent.

Resemblance to, in weathered rocks.

The laterite or more lateritic portion of the plateaus is undoubtedly detrital, but in two localities where there are flat topped hills rising over the general level of the laterite country, there is strong evidence that their cappings may be of ferruginously decomposed gneiss simulating laterite, after the fashion of the lateritoid exposures on the Shevaroys, Nilgiris, or on the west coast at Calicut and on the southern coast of Ceylon. These singular hills are near Rásanur, between the Swarnamukhi and the Sulurpét river, and again at Gurullur, on the left bank of the former river, at some 12 miles from the coast. The latter hill is about 150 feet high, and rises out of the surrounding lateritic country, but its slopes are partly of gneiss, while the capping is lateritic. The lateritic character descends these slopes irregularly, and the foliation is continued into the lateritic

portion, as are also the laminæ of quartz. The gneiss is very ferruginous. In the same way, the Rásanur plateau is of about equal height, the cap being of lateritic rock; but this did not give me any such marked gneissic characters. Laterite may of course have been deposited on the top of these hills, and the ferruginous lateritoid character may have been transmitted to the weathering gneiss below; but it is difficult to account for their caps being so much above the level of the laterite of the rest of the country unless we assume that the laterite below has been denuded down to its present surface from that height. Until, however, the country is more closely examined as to the possible separation of the laterite and lateritic deposits from the Cuddalore grits, I prefer to look on these plateaus as instances of decomposed gneiss.

The Nellore plateau.

The Cuddalore sandstones occur as six slightly elevated and detached patches separated from each other by the main streams flowing to the coast. These are all so much alike in nearly every respect, that a description of one, for instance that of Nellore, will do for the whole. This is the largest and most typical plateau forming a rather elevated stretch of country overlooking the gneiss plains to the west and the alluvium of the great river and the coast, and it runs up into two or three low but conspicuous headlands to the south-south-west of the town and at Survapali, about 10 miles to the south. There is no section, nor are there any records by wells or quarries to show the thickness of the rocks here; but this can seldom be more than 50 or 60 feet. The denuded surface of the subjacent gneiss is, however, so irregular that the thickness varies much. Near Nellore itself, or a couple of miles south-south-west, it is so thin that shallow holes have been dug through it for obtaining large plates of mica from the granite beneath, while only half a mile off there must be a thickness of 30 or 40 feet, or even more. The rocks are more or less ferruginous clays, sandy clayey conglomerates, and clayey gravels and shingle. As a rule, the bottom beds are pale-yellow clayey gravels and shingles, on which rests an indurated ferruginous or lateritic conglomerate, but this loses its pebbly character, when of any thickness, as the surface is neared. All the wells are sunk down to the bottom clayey gravel, and where they are old this

is worn out, leaving the shelving lateritic grit and conglomerate. The upper beds are highly ferruginous and indurated. The Nellore sections disclose irregularly-deposited beds of yellowish-red and mottled ferruginous clays, partly concretionary. There is not much pisolitic laterite here; it is merely a tolerably hard ferruginous gritty clay, much pierced with small vermicular cavities, and there are traces of sandstone-like beds or ferruginous clays full of minute angular pieces of quartz. Away south of Nellore towards Survapali, the rock is more massive and even pisolitic, like the laterite of the Trichinopoly and Tanjore districts, or is often a conglomerate with rounded fragments of quartzite.

More sandy to north of Nellore.

The patches north of Nellore have a greater resemblance to the Cuddalore sandstones of South Arcot and Tanjore, in that they show associated grits and sandstones. At Kovur the laterite is very gritty, passing distinctly into regular grits and sandstones. The following section is exposed in a deep well close to Kovur:—Uppermost a bed, about 15 feet in thickness, of mottled reddish-yellow and brown clayey and sandy laterite, much pierced with vermiform holes. Below this is a much coarser bed of clayey grits, with very thin layers of semi-angular pebbles and gravel of quartz. This bed is extremely coarse and pierced with large vermiform tubes. Average thickness about 10 feet. The thickness of the lower bed is concealed by the water of the well; it is a compact clayey grit, irregularly pitted and honey-combed, but without such decided tubes as are seen in the upper beds.

Charles Oldham describes another locality:—"Detached from the main body of the laterite north-west of Chellum, where just south of Peddawarum (a village outside the northern edge of sheet 77) is a very marked promontory or bluff of coarse ferruginous grits, conglomeratic at base, passing upwards into a pebbly laterite and capped by dark red-brown laterite, more clayey and more closely resembling the typical laterite of the west coast and elsewhere. Of this more typical laterite there is but a thin capping, and the mass of the headland is of a markedly grit-like character."

This bluff or headland is referred to by Foote in his Kistna memoi

as being of Rajmahal sandstones; but, as will be seen in this extract, and again in those already given on the Rajmahal patches, Oldham is, I think, decided in his opinion that the grits and conglomerates forming it are of the Cuddalore sandstones.

(3).—Lateritic Deposits.

Sub-aërial.

The upper surface of the Cuddalore sandstone plateaus is often covered by a thin skin of ferruginous or lateritic breccias and conglomerates, which is evidently a much newer deposit than the laterite of the sandstone group, and which is also as clearly the result of rain-wash and other subaërial influences. It is properly a ferruginously-cemented debris, and is sometimes obviously the weathered or altered surface of the country-rock, whether this be gneiss or recent sandstones. Not only is it formed or spread out over the surface of the Nellore plateaus, but it is found in scattered patches all over the country, particularly at the base of the Kálahásti ranges and in the plains lying below the southern portion of the Veligondas. Several small patches were also noticed by Oldham in the country north of the Pennér, some of which are shown in the map. These outlying patches are found to merge by thin seams of gravel and pisolitic rubble into the heavy recent clayey gravels so frequent all over the Carnatic and in the Cuddapah basin, which I would call the implement-bearing gravels from our having discovered in them the palæolithic quartzite implements so well known in the Madras Presidency. The discovery of these implements was made just after I had left this Nellore country and taken up the northern edge of the Madras sheet, so that we have had no further opportunity of ascertaining their occurrence in the country under description; but from the fact of our having found them nearly everywhere else on this coast in these lateritic deposits and in the gravels, it is highly probable that they do occur in the present area. Some years later Mr. Foote found several implements of this type along the northern edge of this area, the occurrence of which he records in the Kistna memoir.

A source of the ferruginous element in the iron stone beds of Rasanur.

I have already referred to the two low plateau hills of Rásanur and Gurulur or Kota in the southern or Swarnamukhi part of the field, as being capped by laterite, which I take to be decomposed gneiss, and to belong to this sub-division of the recent deposits. There are other, but very small, elevated patches of the same kind occurring among the Potagunta and Gelacapad ridges, which are even more obviously the result of the decomposition of trappoid and hornblendic rocks, which give quite sufficient iron to allow of this form of oxidization and consequent cementation. The Rásanur and Kota hills are themselves of hornblendic rocks, and close by is the very strong and remarkable outcrop of ironstone schists which no doubt were the source of much of the ferruginous matter distributed through the Cuddalore sandstones of this part of the Coromandel, and which, in its excess here, may have given the group the decidedly more lateritic aspect and constitution which it presents.

The ferruginous constitution is also found to extend into the great talus of quartzite debris, and shingle spread along the base of the Veligondas and the other hill masses; in fact in the Kálahásti group and about Yarepet and the Venkatagiri country, the passage of a portion of the talus debris into good lateritic conglomerate and breccia is very evident. A considerable portion of the talus deposits must therefore be included in this sub-group, though I think it is quite clear that this talus must have been in process of formation long before this period, while it is still receiving increments of material from the mountain-wall by the curious stream-like strings of debris which tail up some of the steepest gullies or furrows, and down which the debris is slowly and imperceptibly descending.

(4).—Recent Deposits.

The most important of these are the alluviums and blown sands, there being no very marked display of particular soils. Of the former a kind of distinction can be recognised between those of the rivers and those of the back-waters or lagoons.

Back-waters and coastal alluviums.

The back-water deposits occur in the neighbourhood of the Pulicat Lake and the mouth of the Swarnamukhi, down the Kistnapatam estuary, at the mouth of the Pennér, and over a large area about half-way between Nellore and the northern edge of the field. These areas are still subject to inundation; indeed, parts of them are covered at every tide. The deposits are mainly a dark-coloured sandy mud, which crumbles on exposure into a dark soil, not unlike cotton soil, except that it is largely charged with organic matter. They are generally poor salty soils, not at present suited for cultivation, except in a few places well out of the influence of salt-water flooding. In the spread of this alluvium lying to the north of the Pennér, much of the deposits to the north-north-west of Allur is now under cultivation, and is apparently losing its salty character by fresh-water irrigation. There are naturally other and many different layers in this set of deposits, some of which are sandy and calcareous, while others are altogether of black mud, and there is often as a bottom bed a yellowish-white mottled clay of highly felspathic constitution and consequently extremely sludgy.

Sub-fossils.

Layers of sub-fossil shells and crustacea occur here and there, but more particularly on the shores of the Pulicat Lake and to the north of the Pennér, and these are nearly always in seams of black mud. At Tadacupum or Tada, on the western shore of the lake, these sub-fossils are dug up in great quantities and sent down by the canal to Madras to be made into lime. Those I saw and obtained were from a layer of greenish-black mud, about 3 feet below the surface, underlying a ferruginous pale-yellow mottled clay, which also contains the same shells but only thinly scattered through it. The excavations for shells are made at from two to three hundred yards from the water line. I distinguished the following:—

Murex.	*Pleurotma ? nodifera.*
Pyrula.	*Natica maculosa.*
Nassa, 2 sp.	„ *? globosa.*
Purpura carinifera.	*Cerithium.*
Dolium.	*Potamides telescopium.*

Ostrea.	*Mactra.*
Placuna placenta.	*Lutraria.*
Pecten.	*Tellina spengleri,*
Arca granosa.	" *sp.*
" *sp.*	*Sanguinolaria diphos.*
Cardium.	*Solen.*
Conocardium.	*Solecurtus.*
Diplodonta, 3 sp.	.
Cardita imbricata.	.
Venus cor.	.
Cytherea casta.	.
Dosinea, 3 sp.	.
Tapes, 2 sp.	*Balanus.*

North of Allur (beyond the Pennér), sub-fossils of the same species are common, but not in such numbers as at Tada.

There are also thin seams of indurated sand with recent shells occurring at intervals along the coast at the depth of a foot or so beneath the surface, and fragments of such a deposit, apparently thrown up by the waves, may often be seen along the sea-shore. I observed these more particularly at Sriharikota, about a mile east of Raiaduru, where a shallow pool had been dug in the sandy alluvium, and at the bottom of this is a layer of indurated sand, with remains of *Arca, Cyrena,* &c. Again, on the shore here, at the fishing village, are fragments of a recent shelly sandstone scattered about the beach. At this point the sea is cutting into the bank, exposing a cliff of 4 or 5 feet in sandy alluvium, but I could not find the outcrop of indurated sand.

River alluvium.

The alluvium of the rivers is very various. Those of the Pennér are pale sandy deposits, with more of the brown and humic soils than occur in the deposits of the streams to the south. Along the banks of this river there are only very narrow strips of alluvium, with an occasional band up the tributary streams. Out in the delta spread, there is generally pale-grey sandy alluvium, with good thicknesses of dark-brown and reddish-brown soils with a mixture of lateritic sand and gravel. For the Kandléru, which flows out to the sea at Kistnapatam, there is very little of the pale sandy deposits

except above Gúdúr, all seen below that place being of an estuarine character. The Swarnamukhi valley is strongest in the pale-coloured sandy deposits, a wide spread of which lies behind the line of Cuddalore sandstone ridges.

Blown sands.

The usual strip of blown sands fringing the Coromandel is rather narrow in this field, possibly in great measure on account of the moister north-east wind not being powerful enough to carry the sand far inland, while the drier westerly winds carry much of it back again to the sea. I examined most of the coast line during the hot months (April, May, June, and July), when it was evident that the sand is being constantly blown eastward, the shore being quite hazy with the stream of sand, which rose about 2 feet over the surface of the ground. There is generally a thin sandy strip of about 2 or 3 miles in width which becomes heaped up in low undulations, or is often arranged in long narrow belts with intervening strips of alluvium of dried up back-waters. In the dry weather most of these intervening strips are quite dry, or have a shallow channel open to the tide. The most notable example of this strip arrangement occurs in Sriharikota island, or the land lying between the sea and the Pulicat Lake, and again to the east of Kavali, 34 miles north of Nellore.

The more typical blown sandhills or dunes occur at a point on the coast about 14 miles south-east-by-east of Nellore, at Strinavasarow Chatram, about 18 miles due east of Gúdúr, and generally along the shore of Sriharikota. In the first case, the shore belt of sand towards Toolypoliem is a regular tumbled sea of sandhills ranged in long waves having a north-north-east to south-south-west strike, sloping up gently but quickly from the eastward and dropping down to the westward by steep slopes. Along the northern edge of this spread there is a dense barrier of screw pines and palmyra palms, and here the hills drop down to the green-sward, just like a freshly-tipped railway bank, from a height of 30 or 40 feet. The surfaces of the dunes were beautifully rippled with an east-north-east to west-south-west strike. Besides these fresher-looking accumulations, there are grass-grown ridges a little further inland, extending out as far

west as Goudlapoliem. At the Toolypoliem end, the ridges become separated by grassy bays which tail in from the south, and about here are many instances of palmyras being half-buried in the sand. In the neighbourhood of Strinavásarow Chatram at the mouth of the Swarnamukhi, the sandhills are again very distinct and well marked, but are more separated from each other than those of Toolypoliem. There, the dunes run up to 18 or 20 feet in height, having generally a south-south-west to north-north-east strike, and they stretch a good way inland, often half-burying the palmyra palms.

The narrow northern spit of Sriharikota is marked by long dunes along the Pulicat shore line, this part of the island being comparatively free from jungle, except on the lake side, where the sand has been piled up. The ridges are all striking north-north-west to south-south-east, a change from the usual lie, which is perhaps due to the trend of the coast, here fully exposed to the north-east winds, while much of the sand is sheltered from the southerly winds by the thick and high jungle of the wider part of the island. The highest ridges, from 30 to 40 feet, occur between Sholinduru and Celindar Chattram, and they seem to be only prevented from overwhelming the village of Sholinduru by the large tree jungle close by, many of the trees and shrubs of which are half-buried already. For the rest of Sriharikota, the belt of sandhills widens out much, and is at times run into distinct and well-formed ridges, having the north-north-west to south-south-east direction, and often running up to 15 and 30 feet in height. East of Titupetta, about half-way to the shore, the dunes are, some of them, about 30 feet high, running along the coast in the usual north-north-west to south-south-east direction. These hills are topped with scrub jungle and have their steep slope still to the west.

CHAPTER VII.—NELLORE COPPER WORKINGS.

The mineral or building resources of this part of the Carnatic have already been generally and incidentally noticed, from which it will have been surmised that they are not of any great value or importance, except locally, or because they have not been sufficiently developed.

On northern edge of field.

However, the Nellore district is more particularly known in this connection as having from time to time given promise of good copper ores. The proper region of workings lies just on the northern edge of the present area, and was examined by Charles Æ. Oldham, or on the southern edge of the next area treated of in Mr. Foote's memoir; but I have failed to discover Oldham's notes, and Mr. Foote only refers to this mineral resource very cursorily. My own work did not lie anywhere near this region, so that I only saw the faintest traces, previously noticed, occurring on the right bank of the Pennér, near Yarabully. However, I saw most of the specimens collected by Oldham, and these, with his verbal information regarding them, when compared with the Yarabully rocks, all showed that the copper occurs in a band of hornblendic and garnetiferous schists, with which are associated intrusive sheets of trap. The strings and irregular masses and nests of copper ore occur for the most part in the traps, but they also run with the schists. There is no regular distribution of these in the traps, but the strings run across and occasionally with the laminæ of the schists. No good and tolerably continuous lode is apparent, nor has one ever been found; indeed, the general look of the rocks and of the country is most unpromising, there being very little signs of copper at the surface, the best specimens only being found among the debris from the old workings, while every hole that has been made only shows how all attempts to mine must have been rapidly frustrated by the influx of water.

Results not very encouraging.

Good big lumps of earthy-looking trap are often obtainable, with a good deal of ore distributed through them, which certainly have a very promising look, and this is about the most that can be said of the industry, for all attempts have hitherto failed to produce any encouraging returns; nevertheless I am

not prepared to encourage the hopeless view generally taken of the evidences that have been brought to light by the old workers. In my experience of native workings, I have always found, with the exception of the old gold workings in Wynád, where the men had to deal with an undulating country easily drained, that the mines have never been carried to any depth nor to any extent, as may be easily conceived where the means of getting rid of water, or the supplying of air, were not available. I do not mean to urge the oft—in difficulty or despair—suggested necessity for going deeper in mines to obtain a better result, though of course the wealth may be at a great depth; but I question whether any of these old native mines are ever beyond 60 feet in depth, or that the galleries run more than three times that length. Again, the fact of the place having been tried under European hands and at a great expenditure of money without success is poor evidence of the condition of a mining region in India, for it is even now difficult to obtain competent and steady hands, or even, if they be competent, to guard them against the evil and enervating effects of the climate, and it is above all difficult to arrange for the effective administration of such work. From all I could ever learn of the working of the Nellore mines, these obstacles to progress seem to have occurred in the most exemplary manner. The money seems to have been at hand; but neither Colonel Ouchterlony nor his brother James, nor Messrs. Hart and Simpson seem to have been capable of carrying on or organising the administrative part of the affair; while solitude, sickness, and drunkenness were too much for the miners.

Occurrence of this ore at Garimanipenta.

The localities appear to be principally within the outlying zemindari lands of Kálaházti. Those visited by Mr. Oldham are at and in the neighbourhood of Garimanipenta (Gunnipenta) on the northern edge of the sheet, and within some 24 miles of the western hills. The specimens he produced were principally copper glance in irregular masses, with strings of malachite occurring in massive earthy trap and in hornblende schists. They were all from the heaps of debris thrown out of the excavations which had been made near the village. The traps appear to occur as intrusive sheets running

with the schists, but the ore in the latter is in nests or strings running with the foliation, and nothing is known as to the lie of the irregular masses in the traps, these all being from debris.

Latest explorations of Mr. Lavelle.

The latest information regarding these occurrences—and they do not give much more clue to the extent of ore or its lie—has been obtained by Mr. Lavelle,[1] an enthusiastic and energetic explorer, though perhaps too apt to take a florid view of his finds.

The villages examined by Mr. Lavelle are nearly all in the neighbourhood of Garimanipenta, and the specimens obtained by him have been examined by my colleague, Mr. Mallet, whose notes I also append. Mr. Lavelle writes :—

"I arrived at Gurumanapettah on the 8th November, and commenced prospecting for copper next morning, and was successful in finding some good samples from several water-courses. Many lodes are to be seen in outcrop.

"On the morning of the 10th I started with three gangs of coolies to examine the lodes, so as to determine which to commence work on.

"I commenced on a lode ¾ mile south-east from the village, and opened on the highest point of outcrop; as the weather looked monsoony, and as I was about to work in open pits, in the event of rain and my working on the dip of the lode would flood me out.

"I commenced work by marking out 60 feet along the line of reef, and 22 feet on the dip.

"The outcrop being very poor, led me to believe I would have to go some depth before meeting with ore fit to send to Madras, but was agreeably surprised to find the ore getting richer at every foot of sinking, and at 5 feet from the surface the ore had improved so much that I began to stack it for despatch to Madras. I continued the sinking on the west end of the trench to 9 feet deep and 20 feet long to east. The bearing of this lode is 285·30 from outcrop along the line of reef, and can be traced for a long way in outcrop.

[1] These notes have been placed at my disposal by gentlemen for and with whom Mr. Lavelle is carrying out mining explorations.

"The dip is 68° south; the country rock is mica slate and decomposed; the lodes have a casing of laminated trap and the ore is found in quartz reef, the trap forming the head and foot wall.

"The assay of the ore from this reef made by Richardson & Co., of London, was 28¾th per cent. pure copper.

"The thickness of this reef is about 2 feet 7 inches where I worked on it, but I have reason to believe, from two blows of quartz to the west of my working, that the reef is much larger than where I cut it; but, as I have above stated, it would not do for me to open on it where I was likely to get a rise of water, and the object of my visit to the field was merely to see if the reef would pay, so as we might arrange for them with the Rajah of Calastry, in whose ground they are; and further I knew that by sending ore from outcrop and 9 feet men of practical experience in England would be able to form a very good idea as to what would be the value of the lodes in depth.

"After satisfying myself as to the lode continuing in depth, I ripped up some 55 feet along its line to east, to prove its continuing in that direction, and to get its true bearings.

"After satisfying myself on those points, I abandoned this lode.

"The ore is very easily got, and you can judge from the following statement what the cost of raising a ton will be:—

Commenced work on 11th: coolies	...	...	Rs.	8	0	6
" " 12th: "	...	...	"	9	9	3
Water rising fast, 9 feet; 13th: "	...	...	"	9	9	3
	Total	...	Rs.	27	3	0

"Work done:—

Opened up (115×32×9) cubic feet, through Morambo or decomposed gneiss, baled water, and took out ore to the weight of 7 or 8 tons, besides poor outcrop, down to 5 feet, for Rs. 27-3-0; or removed 33,120 cubic feet of ground for the above sum.

"These figures will serve as a data for making a rough calculation as to the cost of raising ore. The general remarks will give a data to calculate from as to cost of carriage, smelting, &c.

No. 2 Lode.

"On the 14th I prospected and discovered a second lode in outcrop, about a mile from the village to the east. As on the first lode, I com-

menced work on the highest point and worked to the west. Ore in outcrop is to be seen in the water-courses, many of which run from south-east to north-west, from which a large tank is filled during the monsoons. The head and foot wall of this lode is well defined, and can be easily followed on surface for over 2 miles, and in one place where a well was sunk for irrigation, the lode was cut, this well being about a mile west of where I worked on it. The thickness of this lode is over 3 feet; its head and foot wall, trap slate or highly laminated trap, and easily worked.

"I raised several tons of ore from this mine, and some tons were sent home, but I have not heard anything about it. I believe it was lost, but the result of an assay made from a parcel sent to Messrs. Richardson & Co., of London, was over 50 per cent. pure copper.

Memo. showing the cost of opening up grounds and raising about 10 tons of ore; a large quantity now on the ground.

15th.	Men and women coolies	... ...	Rs.	8	14	9
16th.	" "	... ...	"	7	3	3
17th.	" "	... ...	"	9	1	4
	TOTAL	...	Rs.	25	3	4

Opened ground (62×15×6) cubic feet, or 5,580 cubic feet.

No. 3 Lode.

"Close to the village and to the west of north.

"This lode is in the bed of a large tank which happened to be dry, and I commenced work on it and struck it after removing some 9 feet of silt and tank deposit, but had barely time to remove a small parcel of ore, when a heavy shower came on and partly filled the tank, flooding me out.

"The ore removed was the richest found by me, the assay being 54 per cent. copper.

"I could not, for want of time before the rain, determine the thickness, dip, and course of this lode.

"Many lodes of copper ore are to be seen in the vicinity of Guramanapettah, three of which had been tried by non-professional miners, who

dug great holes and found it would not pay, and I must say no amount of copper would pay the way they went to work.

" One of those old workings is to the north of the village and in hard trap (or compact), and some thousands of cubic yards were blasted to follow the lode on the dip.

" In every attempt made at mining in those fields, the surface was only scratched, and no attempt made at sinking.

" Those copper lodes must have been known to the natives, but they did not consider them sufficiently rich to work.

" The field known as the copper-bearing country and worked by the natives lies to the north, in the Rajah of Vencatagherry's territory.

" Very large old workings are to be found in the vicinity of Gorganpully, about 30 miles to north of Guramanapettah. Some of those old workings are carried down 100 feet, and several hundred feet long.

" The old mines in the Vencatagherry territory and near Gorganpully were vigorously worked for the Nabob of the Carnatic, and the ore smelted and sent to his palace or gun factory before the year 1780, but as British arms triumphed, those as all other mines in India declined, and on the assumption of any territory by the British, mining entirely ceased, and now the natives will endeavour to lead Europeans astray, as to the whereabouts of all mines, especially the Brahmins; and the only people information can be got from, is the working class.

General remarks.

" The copper zone or belt runs nearly north and south along a valley bounded on the west by the Doranal range of mountains, and on the east by a series of small outlayers or range of low hills. A belt of jungle of several miles long and 12 miles wide divides the field from the new canal, which is about 20 miles from the field. From this jungle, charcoal can be had at a very low rate, and on the west near Gorganpully, large timber for mining purposes, and charcoal from the same forest, are very cheap. Cartage is scarce, as no roads run through the field, but along the coast, road cartage is plentiful, and as the country is favourable to road-making in being very stony and no heavy alluvial deposits, the

difficulty of cartage to the canal and coast could be easily got over. A good cart-track could be made for £20 per mile.

"The field at Guramanapettah is within 9 miles of a public road, which leads to the canal at Kavely, and the ore from Gorganpully could be taken to Ramaputnam about 20 miles. A cart carries 40 maunds for 10 miles per rupee, and boats can be had at Rs. 2-8 per ton to Madras."

Ores obtained.

I have only been supplied with small samples of the specimens referred to above by Mr. Lavelle, the bulk of these having been, I believe, sent to England for assay; consequently no satisfactory assay of the ores could be made. The samples were—

A.—Chrysocolla (in garnetiferous schists, of which the garnets, though small, might from their colour and transparency be called precious garnets).

B.—Copper glance (chalcocite), chrysocolla, malachite.

C.—Chrysocolla, malachite and ferruginous red oxide? (Mysorin).

D.—Copper pyrites, chyrsocolla and malachite in limonite.

F.—Copper glance with chrysocolla and malachite.

G.—Copper glance, malachite and chrysocolla.

And other specimens of the same kinds.

Prinsep's assay of the ores in 1836.

An analysis[1] of the Nellore ores was made in 1836 by Mr. James Prinsep, the then Assay Master of Calcutta, and he gives the following results for three packets of ore:—

	No. 1.	No. 2.	No. 3.
Hydrated carbonate of copper	52·4	68·5	31·7
Sulphuret of copper	0·0	0·0	63·0
Sulphuret of iron	2·1	12·4	0·0
Oxide of iron	43·5	25·1	5·3
Loss or excess	2·0	—6·0	0·0
	100·0	100·0	100·0

[1] Madras Journ., Lit. and Sci., Vol. III, O. S., p. 154.

He says further: " Mr. Kerr, who has since visited the whole of the mining district and examined all the formations and the old works with great care, states that the former excavations are of prodigious magnitude, many of them occupying several hundred feet square, and having a depth of 50 or 60 feet. The matrix rock and rubbish are now accumulated in three enormous tanks (? banks), but on clearing them away the mouths of the galleries extending into the rocks were discovered: blocks of the ore have been used to mend the village tank at Guramanipenta, and Mr. Kerr imagines that any quantity of the richest ore may be obtained at a trifling expense and within a hundred feet of the surface. Extensive hills formed of lumps of ferruginous slag, now covered with vegetation, point out the situation of the ancient smelting houses.

"The richest ore of the three is at the same time the most abundant, and promises to yield the safest return, as it runs in unbroken veins. This ore is a combination of carbonate and sulphuret, the former intermixed with the latter, but readily distinguishable from it, as the sulphuret is crystallized and has the grey metallic lustre of galena. The specific gravity of this ore is 3·77, being intermediate between that of the carbonate, 3·2, and the sulphuret, 4·5."

History of the copper working.

The history of the Nellore copper mines is given in Mr. Boswell's Manual of the district; and I here take the liberty of appending the following extracts from that work:—

"In 1801, copper ore was discovered in this district. Mr. J. B. Travers, Collector, in letter to Board, dated 7th January 1803, submitted proposal from Captain Ashton for working the copper ore then lately discovered, in the Western Pollums. The vein first discovered was near a village (Yerrapilly), and appeared to have been exhausted from excavations in the vicinity. The inhabitants said that copper had been made there in former times; they knew from tradition and nothing more.

" Subsequently very extensive veins were found in the neighbourhood

of Gurmanipenta, 4 miles west of Yerrapilly. Mr. Travers opened two veins, which he followed about 20 or 30 feet. The openings were about 4 feet in diameter, and ran into the earth at about an angle of 45 degrees. The ore was found in masses breaking off for 2 or 3 feet and again appearing. The veins ran obliquely towards the beds of the deep rivulets. The ore found at Gurmanipenta had a different appearance from that found at Yerrapilly, the latter not being so blended with spar as the former. Among the specimens were some very beautiful and perfect crystallizations and some pieces of a very dark iron appearance and a very black-green, which two descriptions upon experiment with a blow pipe and a piece of charcoal were found to yield 75 per cent. of copper without the aid of any flux. Other specimens of ore by experiment by fire and acid were found to yield from 20 to 70 per cent. of metal. Specimens of the copper were sent home and assayed. Although not equally rich in the metal, they were found to be remarkably fusible, very free from iron, and consequently well adapted for sheathing. These mines were in consequence leased to a contractor for five years by the Government. It was thought that the direct interests of a speculator would naturally stimulate to greater exertion and a more economical expenditure in effecting the object than could be expected from the employment of a Government agent, the latter having an immediate reward for his labour in a competent salary, whatever his success might be, whereas the speculator would be compelled to complete his purpose on the most prudent plan and least loss of time, as he would depend on its accomplishment for his reimbursement. One specimen of the ore weighing 20 cwt. yielded 9 cwt. 1 quarter.

"The principal places where the copper ore was found were about 50 miles north-west from Nellore, 30 from the sea, and about 40 north-east from Cuddapah. Several streams traverse this portion of country, on their way to the sea, and the junction of two of them forms a considerable river at Gurmanipenta, although not navigable. Among the valleys wood of a large size grows abundantly, and in the direction of Ramapatam there are extensive jungles."

Mr. A. M. Simpson (once connected with the firm of Hart & Co.),

and long resident in the district, supplied further information for this Manual, of which the following is an extract:—

"The ore is rich in metal, some specimens having yielded 75 per cent., but imbedded in a very hard matrix difficult to be worked. It is found in large and small masses of quatrz, and, so far as I have been informed, no continuous vein has ever been discovered. All the specimens that I have seen have had a more or less rounded surface, indicating their having been subjected to the action of water, and rolled possibly in former times from a considerable distance.

"Deceived by the abundance of the ore lying on or near the surface and by old excavations, and the traditions of natives that at some former period copper mines had been worked, several enterprising individuals, during the first half of the present century, expended a great deal of money in preliminary mining operations, but do not seem to have carried them on a very extensive scale, or to have brought much scientific knowledge to bear upon them. Mr. Ashton, Captain Kerr, and Mr. Fondclair, I believe ruined themselves in their vain search, and Mr. Hart at a later date expended upwards of a lakh of rupees with a similar result. Mr. James Ouchterlony, in or about the year 1840, under the superintendence of an experienced Cornish miner, whom he brought out to the country for the purpose, sank one or more shafts near the river at Gurmanipenta, but he met with no more success than his predecessors. Mr. Ouchterlony's brother (the late Colonel Ouchterlony, of the Madras Engineers) in 1841 or 1842 printed for private circulation a pamphlet, illustrated by drawings of various specimens of ore that have been found. In it he gave a detailed account of what had been done by his brother and his predecessors, and I believe he arrived at the conclusion that further explorations would be a vain waste of money and inevitably lead to disappointment."

King.

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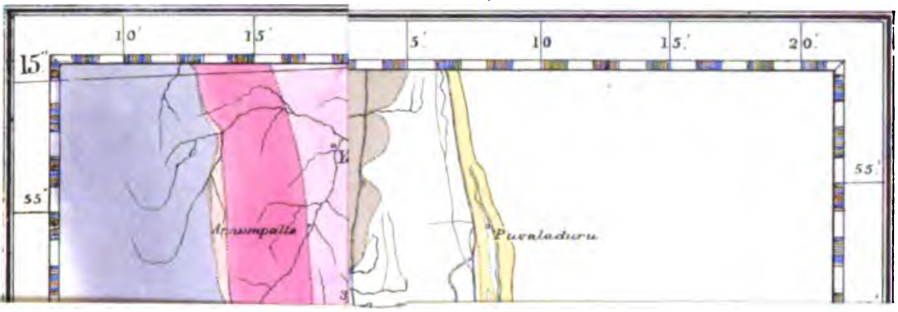

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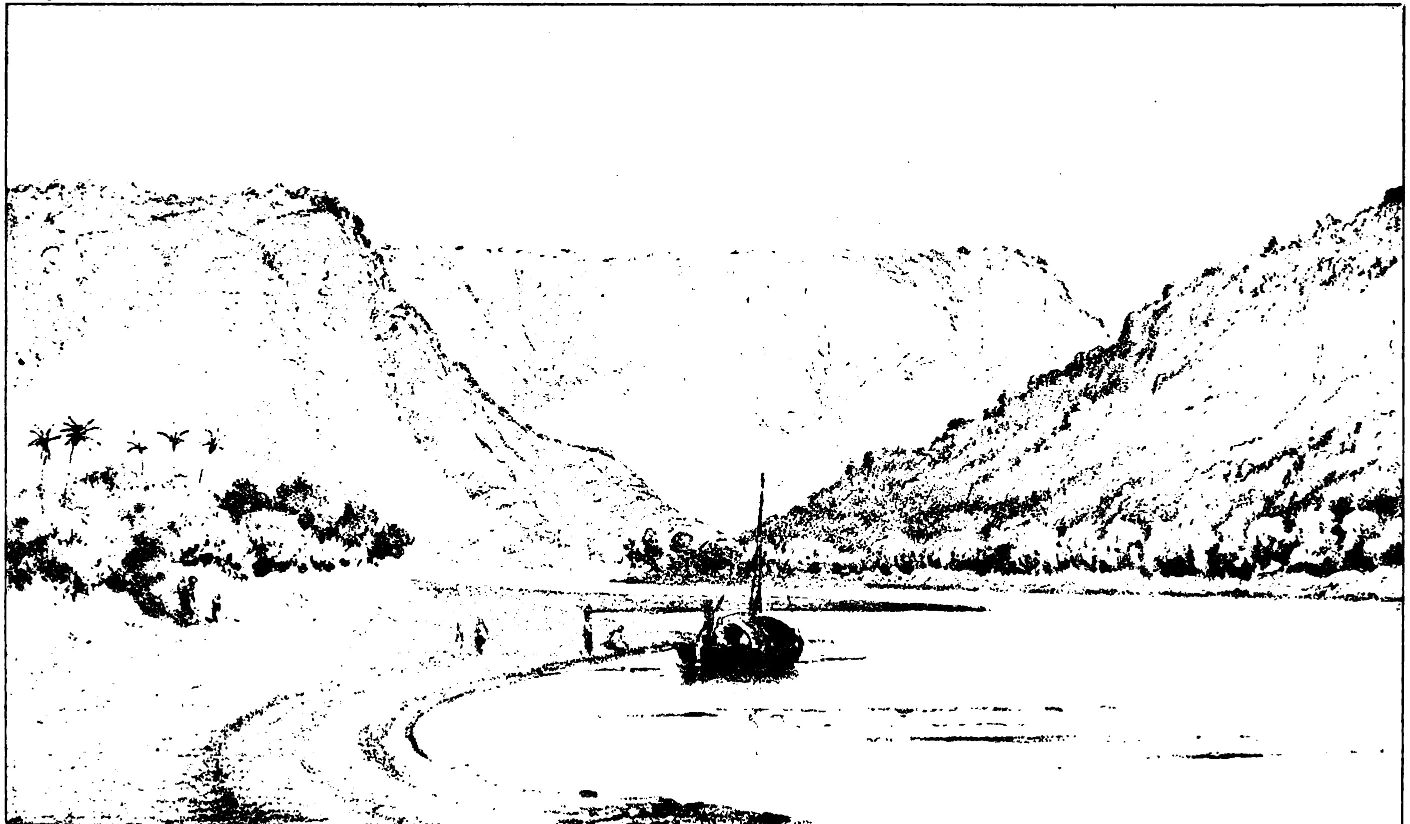


J. Schaumburg. Lithᵍ.

W K. Del.

GORGE of the GODÁVARI from the South.

MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA.

THE UPPER GONDWÁNAS AND OTHER FORMATIONS OF THE COASTAL REGION OF THE GODÁVARI DISTRICT. *By* WILLIAM KING, B. A., *Deputy Superintendent* (*Madras*), *Geological Survey of India.*

CHAPTER I.—GENERAL DESCRIPTION.

Introductory.—The great tract of Gondwána rocks occupying the lower half of the Godávari valley is very conveniently and advantageously divisible into two areas, which are separable, physically, by that portion of the Eastern Ghâts sometimes called the Golgonda range of mountains, and, geologically, in that the upper division of this formation is in great part of marine origin to the south of the hills while there are only river and lacustrine members of the series in the upper part of the valley.

The portion below the Ghâts, or, in other words, the coastal region, also corresponds to what is called, in local parlance, the lower division of the Godávari district; and this is the area treated of in the present Memoir.

The principal formation to be described is thus a part, though in many respects a very important part, of its development on the Coromandel or Eastern Coast in the patches already examined or described[1]

[1] See Parts 1 and 2 of this Volume, and Vols. IV, Parts 1 and 2, X, Part 1, Memoirs Geol. Surv. of India; also Records, Geol. Surv. of India, Vols. III, p. 11, XI, p. 249, XII, p. 187.

by the Survey, as extending thus far northwards from the Trichinopoly district, through Sriperumbudar (Sripermatur), the Nellore area, and so up to the Kistna.

The other formations to be noticed were nearly all known, more or less, long before the examination of the country was taken up by the Survey; this region having been rendered classic ground by several of the pioneers of Indian geology, more especially through the researches of the late Revd. Mr. Hislop into the relations of the inter-trappean fossil beds in the neighbourhood of Rájahmundry. It was, however, reserved for my colleague, Mr. W. T. Blanford, to trace the Gondwána series down the valley of the great river from the Central Provinces in the year 1871; and in 1873 I had the good fortune to discriminate some groups of the upper division of this formation, as also some infra-trappean beds, to increase the roll already made out by unofficial observers.

Literature.—The work of these latter explorers commences as far back as 1814, when the 'Tracts, Historical and Statistical, on India' of Dr. Benjamin Heyne appeared. These contain many references to this part of the peninsula which are extremely interesting, and they shall be duly noticed in the following pages, as they may happen to bear on the rocks or formations under description.[1] In 1830, H. H. Voysey, Surgeon and Geologist to the Great Trigonometrical Survey, travelled over the western edge of this area, and his reports were subsequently collected and published in the Journal of the Bengal Asiatic Society.[2] He refers to the diamond mines at Muléli, near Ellore, which even as far back as that time were not being worked. He also noted that the sandstone tract, now known as of Gondwána age, was traceable all down the Pránhita-Godávari valley into the Ellore country. In 1835, when the

[1] Tract III, p. 92, *et seq.*—Account of the diamond mines of India. Tract XII, p. 212—Account of the method of smelting iron in the Northern Circars. Tract XIII, p. 224—Account of the iron works at Ramanakapetta. Tract XV, p. 230—Cursory observations made during a tour from Bezwáda to Timmericotta. Tract XVII, p. 247—Observations made on a tour from Samulcotah to Hyderabad. Tract XVIII, p. 280—A brief account of the Circars on the Coast of Orissa.

[2] Vol. III, pp. 298 and 392 (1833).

then Governor of Madras was making a tour in the Northern Circars the medical officer, Dr. P. M. Benza, took the opportunity of looking up points of geological interest which were published in the Madras Journal of Literature and Science;[1] and in these is, I think, the first published notice of the now well-known occurrenee of traps with intercalated and subjacent fossiliferous beds in the neighbourhood of Rájahmundry. The peculiar character and constitution of the gneiss in the neighbourhood of Bezváda, and thence along the west to Vizagapatam, were first noticed by the same writer. In 1837, Mr. J. G. Maleolmson read a paper before the Geological Society of London,[2] wherein he refers, incidentally, to some of the roeks of the lower Godávari region.

Captain Newbold passed along the western edge of this area, some four or five years later, in one of his tours across the peninsula, when he made some further observations on the rocks of Bezváda and the old diamond mines at Maléli, which were embodied in one of his many 'notes.'[3] Mr. Walter Elliott, M.C.S., then stationed at Rájahmundry, worked at the inter-trappean beds of Kátéru in 1850; and in 1854 he sent a collection of the fossils obtained from that place, with notes, to the Asiatic Society of Bengal.[4] In 1855, these Kátéru beds and those of Pungadi on the right bank of the Godávari were again brought to notice[5] by the Revd. Messrs. S. Hislop and R. Hunter, and again, in 1860, a further paper[6] was contributed by the previous gentleman which deals more closely with the same rocks. Mr. Hislop never personally visited these localities, so that he had to depend on the old observations of Dr. Benza, and later information obtained for him by Lieutenant Stoddard. Colonel Stoddard has since informed me that

[1] Notes, chiefly geological, of a journey through the Northern Circars in the year 1835, Vol. V, 1837, pp. 43—70.

[2] On the fossils of the eastern portion of the Great Basaltic District of India: Trans. 2nd Ser., V, p. 537.

[3] Journ. As. Soc., Bengal, Vol. XIII, 1844, pp. 984—1004.

[4] Journ. As. Soc., Bengal, Vol. XXIII, p. 397.

[5] On the geology and fossils of the neighbourhood of Nágpur, Central India—Quar. Journ. Geol. Soc., Lond., Vol. XI, p. 365.

[6] On the tertiary deposits associated with trap rock in the East Indies—Journ. Geol. Soc. Lond., Vol. XVI, 1860, pp. 154—166.

he had no technical knowledge which could have enabled him to give reliable details, and Benza's observations were in some respects inaccurate: thus the relations of the beds are not correctly stated, and some erroneous conclusions were drawn therefrom which shall be noticed in their proper place.

Topography.—The country under description has somewhat a lozenge-shaped outline, with its longer diagonal striking east-north-east from the neighbourhood of Bezváda, on the Kistna, to a point on the sea-coast, about 45 miles south-west of Vizagapatam. From this point the shore forms one edge, running still south-west to about the 16° 20' parallel of north latitude, which parallel, again, is the southern edge of the field. The two other sides, namely, those on the north and north-west, meet in that part of the Eastern Ghâts culminating at over 2,400 feet in the Kaurkonda and Pápakonda range, which is here crossed by the grand gorge of the Godávari.

The larger and central town is Rájahmundry, next comes Coconáda[1] the sea-port and zillah station, and the minor towns are Bezváda and Ellore.

Physical geography.—The country is mainly low-lying and alluvial, more than half of it consisting of the deltaic deposits of the Godávari and a portion of those of the Kistna, and this is to the north-east joined on to a wide stretch of the alluviums of the minor streams on the edge of the Vizagapatam district. From this flat there is then a gradual rise which is broken by many small hills and groups of these, more especially in the Rampa country, until the greater masses of the Kaurkonda-Pápakonda range are reached.

Delta lands.

The uniform level of the great alluvial plain is broken by a large outlier of gently rising ground, an island as it were in the alluvium, at either end of which lie the towns

[1] I have accented the name here, though it is not marked so in the official list, the proper name being Kákináda (the place of crows). Of course, it must be often rather difficult for strangers to tell how these Indian names should be pronounced; and a story to this effect is told of a child of a former collector of the place, who was rather taken aback on entering school in England at finding himself corrected in his pronunciation of the name of the town in which he was born, which the master improved into Cocánada, as though it were related to our possession in America.

of Rájahmundry and Sámalkót (Samulcottah); and again, but in an extremely smaller way, there are a few elevations in the north-east plain, as near Pitházpuram and Ayaparáz-Kotapili, or still nearer to the rising land, the very picturesque group of tolerably high gneiss bosses in the alluvial bay of Lingumpurra. At the Bezváda end there are also a few similar alluvium surrounded hilly masses, two of which, on either bank of the Kistna, have been joined together by the great dam there built across the river and giving a head to the splendid system of canals distributed over its delta. Indeed, at the remote period when this great alluvial plain was occupied by the sea, the then Godávari coast must have been eminently varied in its contour, from the Bezváda islands in the Kistna bay past the large island on which the pleasant bungalows above Dowlaishweram now stand, and so by the many curving bays of Kirlumpúdi, Túni, &c., right up to the Dolphin's Nose and numerous other fine hilly masses in the neighbourhood of Vizagapatam: a very different style of scenery to that now exhibited along the low and uninteresting shores of the Coromandel.

Low country and hills.

From this old coast line the country in the middle area rises very gradually by long-backed sandstone hills which drop down again in low parallel escarpments facing north-westward, and beyond these there is further low-lying but broken ground, marked more particularly by the Chintalpúdi hills. In the Bezváda area the country is still very flat, but there are several low hills and ridges rising out of it such as the groups around Augerpali and the larger masses of Vellatúr and Kondapilli. Over the north-eastern country, low hillocks rise immediately from the edge of the alluvial plain having a long and quite even slope to the south-east and a much steeper fall to the north-west; and these are succeeded by rather flat-topped ridges, rapidly increasing in number and height towards the more hilly Rampa country.

Rivers.

The important local rivers are the Tammilér, flowing past Ellore into the Kolér lake; the Yera Kalwa, draining much of the country below the Kaurkonda or Bison

Range; and the Eléru, Golgonda, and Pandáru rivers in the Rampa and Vizagapatam area; but the country is cut right across by the waters of the great Godávari river which have been collected behind and far to the north-westward of the Eastern Ghâts through which the famous gorge or defile passes (See plates 1 and 2).

The Godávari gorge.

The mountain passage of this river is a deep and tortuous trench, with a V-shaped section of about 12 miles in length, of which 4 miles in the middle may be said to be the proper gorge, the river being here about 300 yards wide,[1] while the mountain spurs rise more abruptly to a height of over 2,000 feet. Here the river is more like a loch or fiord lying among lofty mountains, and it is often difficult, as one is floating along, to guess where any outlet can be, specially when the lofty flat-topped 'Bison Hill'[2] is in front (See Plate 2). But the wonder of this river-pass is, as to how and why it should have been cut down through this 2,000 feet high range of crystalline rocks, when to all appearance the river might have pursued its course through the more easily-worn sandstone of the low water shed[3] to the south-west, near Ashwaraopet where the great gap (crossed by the Kistna) in the continuity of the Eastern Ghâts commences.

[1] Mr. Vanstaveren, lately resident engineer on the Upper Gódávari, informs me that the narrowest part of the gorge is 832 feet across; the deepest sounding taken by him was 121 feet, with a bottom of soft blackish clay, the shallowest parts being 63 feet. The bottom towards the sides is very uneven and rocky, but the mid-channel is pretty even.

[2] Another name for the Kaurkonda hill, overlooking the right bank of the river, said to be over 2,500 feet in height, and one of the few spots in this part of the Presidency still frequented by bison. An attempt was made several years ago to utilise this plateau as a sanitarium for the men employed on the works at Dowlaishweram, but it was found to be feverish, and the supply of water was poor.

[3] I have not been able to obtain the level of this water-shed above the sea, but it can scarcely be more than 200 feet. The country is wonderfully flat at the shed and away down on either side of it; in fact, it appeared to me that the height can hardly be so much as this. At any rate, there is a tradition (told me by Mr. Vanstaveren of Damagúdem on the Godávari, formerly Executive Engineer at that place) among the people that the Godávari was very many years ago so ponded up behind its gorge in a great flood, that its waters actually poured over this water-shed! This appeared so amazing a phenomenon that we could hardly believe it. However, subsequently when working at the Beddadanol coal-field

J. Schaumburg. Lithd. W. K. Del:

Narrows of GODÁVARI GORGE – (Looking South).

Of course, the obvious view of the case is, that the Ghâts and the great valley of Bhadráchalam behind them have all grown with the denudation of this part of the river, which commenced to eat its way into the earth as the upper surface (or thereabouts) of the Pápakonda range rose out of the sea; but still there is the great difficulty that the field of harder rocks should have been attacked rather than the sandstone area to the south-west.

Its history.

A reference to any good map of India will show that the Godávari for some 30 miles before reaching the gorge, and in the neighbourhood of its passage from the sandstones to the gneiss area, follows a remarkable bend nearly at right angles to the generally south-south-east course it has pursued for over 100 miles between Sironcha and Bhadráchalam. At the same time, this area, or the mountain region of Pápakonda, and the lowering hills between it and the alluvial flat of the coast, exhibit plateau and bevelled surfaces which are the remains of an old

on the south side of the shed, Mr. Vanstaveren made further enquiries among the oldest inhabitants of the neighbourhood, when he obtained confirmatory evidence. It appears that there have been three well-ascertained great floodings of the Godávari, namely, in the years 1818, 1849, and 1861, the earliest of which was tremendously high, and 20,000 people are said to have been carried off by it on the Nizam's side of the country. Mr. Vanstaveren asked a man incidentally if he could point out how far the waters of 1861 approached within the neighbourhood of the water-shed; the man pointed out a village not far from the northern edge of the divide. On this, Mr. Vanstaveren is inclined to think that it is quite possible that the greater flood of 1818 must have really overflowed and carried the Godávari water into the valley of the Yerakalwa. Mr. Vanstaveren, who has perhaps had more practical experience of the Godávari river than most men, says that the water rises in the gorge at least 100 feet in heavy flood time. Colonel Beatty, the District Engineer in 1878, in answer to some enquiries I made regarding the river, says, "the depth of the river in the gorge has never, so far as I know, been carefully recorded. In summer, when there is no perceptible current, the depth is supposed to be about 80 feet, and in maximum floods it is supposed the water rises 100 feet over summer level, so that there would then be about 180 feet at the gorge." Hence on my supposition of the height of the Ashwaraopet divide, the water would have to rise in the gorge at least 70 feet higher before it could possibly flow into the Yerakalwa valley. However, this is little more than guess-work, and therefore the tradition must be let stand for what it is worth until the height of the water-shed is obtained. The people are doubtless given to exaggeration in many things; for instance, they might have a tradition of a great flood that overwhelmed a countless number of people, but they would hardly take the trouble to invent a story of such a phenomenon as that those waters flowed over a particular water-shed.

marine plain now having a gentle slope of two or three degrees to the south-east, the elevation of which plain above the sea would appear to have commenced at the end of the jurassic period.

I would venture to suggest that this trending of the river so much more to the eastward may be attributed to an elevation of the land with an initial slope such as is presented by the present surface configuration of the hilly country; while concurrently with this elevation, the denuding power of the river would be gradually directed to and kept working in the harder crystalline rocks.

This abrupt swerve in the river's course was more particularly brought to my notice by the late Dr. Oldham in connection with corresponding deviations from their general or average courses in the Kistna near Kurnool, the Pennér near Cuddapah, and the Cauvery at Kerúr, which he seemed inclined to think indicated a period of physical change of considerable importance in the geological history of the peninsula. Further study of these rivers and of the rocks traversed by them may help to develop this generalisation; but so far the course of the Godávari below Bhadráchalam does appear to be one of the marks of a middle mesozoic period of great change in the eastern coast of India.

Delta branches of Godávari.

The alluvial banks on either side of the gorge between the hill spurs, are left as a well-marked terrace fully 70 or 80 feet over the level of the dry-weather waters. Below it, or near Poláwaram, the alluvium begins to spread out widely on either side, the flood waters being now kept back by artificial banks all the way down to the commencement of the delta at Dowlaishweram, a few miles below which town the river bifurcates, the Gowtámi branch going off towards the northern mouth at Hope Island, while the Vasista branch flows in the direction of Bendamúrlanka and again bifurcates, giving one outlet near the latter place and the other and larger near Narsapúr.

System of irrigation.

The delta waters have now for many years been distributed by a magnificent system of navigable and irrigation canals over the great alluvial plain, and are even

in communication with a further great system on the Kistna delta, the junction being at Ellore, which again within the last year or two has been connected with the coastal canal from Madras. The Godávari system has been effected by a great dam or '*anicut*' which is built across the river at Dowlaishweram, at either end of which and in the middle are locks leading the waters into what are called the eastern, western, and central deltas, the latter being between the two branches of the river. At flood-time the anicut is completely covered, the only evidence of its existence being a broad wave across the river's course. The height of a maximum flood at Dowlaishweram is about 53 feet above mean sea level, and at the gorge it is supposed to be about 150 feet; so that there is a fall of about 97 feet from here to the *anicut*, that is, in a distance of about 45 miles. The current of the river at that time through the hills is so great that the most powerful steamers of the Godávari works fleet cannot make any head against it.[1]

The Kolér lake.

The great alluvial plain of the coast is broken by a large surface of inland brackish water called the Kolér lake, into which the Tammilér river empties itself. This lake is very shallow, and is situated about midway between the Godávari and the Kistna; and it seems to be obviously a hollow which has been left between the gradually growing deltas of the two rivers which has not as yet been filled up by the deposits of the smaller river, though this has undoubtedly spread out a delta of its own in the bay between the long low uplands behind Ellore and thus helped to give the even north-west shore line. The lake is in tidal communication[2] with the sea in the dry weather by the Upputéru, a stream at its eastern end

[1] Mr. Vanstaveren, who has occasionally made the voyage on the river at these flood times, tells me that in the gorge the surface of the river has then a very hollow section and that the voyager races away as it were in a trench of water; and that just below the pass there is all the sensation of going down a slope, or working up one as the case may be. The great flat-bottomed stern-paddle steamers are often tried up this visible slope before the current diminishes sufficiently to allow them to proceed.

[2] Colonel Beatty writes: "When I visited the head of the outlet in May 1876 it was open, and the water in the mouth (which was some 100 or 150 feet broad) rose and fell about 3 feet with every tide.

near Akíd; but when the Tammilér is in flood, there is then a current outwards. As the dry weather comes on this outlet is closed and as much water as possible is retained for irrigation, &c., along the shores. Occasionally, as in the year 1875, the Tammilér comes down with great force and floods the country all round Ellore. In that year the banks of the canal, which is here below surface level, had to be cut to allow of the water being carried off partly by it, the river waterway under the aqueduct not being sufficient for the off-flow.

Such are the more evident physical features of the country, but a further remarkable one, and not so patent to the casual observer, is a certain bevelling off, or truncation, of many of the hills and ridges into pseudo-plateaux from the smaller elevations along the edge of the alluvial plain even up to the loftier masses of the Eastern Ghâts at the river gorge; all which bevelled surfaces appear to have been portions of one great and ancient plain which has since been denuded and cut into, in fact, the remnants of a deeply denuded old marine floor. In the Rájahmundry-Vizagapatam area, the hills have all very much the same gentle and even sloping surfaces hading up out of the alluvial flats, while the hills and ridges a little further inland have their summits bevelled off in what appears to be the same plane. This is a marked feature of the hills about Kirlumpudi and Bendapudi, and I noted it at the time of my survey as a strange one. Subsequently, in working over the country to the north of Rájahmundry, about Korakonda and Nágumpali, I was again struck by the curious planed-off aspect of most of the hills, their tops all appearing to lie in a plane of gentle south-south-east slope which should meet the flat-topped Bison hill in the Ghâts. The same feature is seen, though less vividly, in the Yernagúdem and Ellore country, from the low hills near Gútálla to the higher group near Chintalpúdi. Again, towards Bezváda, in the numerous hills about Núzvid, Augerpali, Núna Stalum, and Bezváda itself, there is the same lie of the hill and ridge tops in a generally south-easterly sloping plane, displayed in a remarkably clear manner.

Traces of an old marine floor.

This old marine floor is, as shall be shown later on, made up of gneiss, and, in one portion of the field, lower Gondwána rocks (presumably ranging up into triassic times); while upper Gondwána strata (of ascertained jurassic age) are lying evenly over both of these. It is therefore clear that this floor is of pre-jurassic age; while the history of this portion of the Eastern Ghâts and the great river defile through them can only be considered to have commenced after this period.

Its age.

The different groups of rocks occurring in this field are given in the following list, in which they are ranged as closely as possible with the groups of the survey classification, and approximately so with the like sub-divisions of the European formations. The crystalline rocks, of which there is a large area, and the sandstones of the lower Gondwána series have not yet been examined in sufficient detail to admit of final description; hence they are only treated of cursorily in this Memoir, and as the floor-rocks on which the other formations more particularly described are laid down.

List of formations.

Local groups.		Groups of Survey classification.	Approximate position in European classification.
Alluvium.			*Recent.*
Rájahmundry sandstones.		*Cuddalore sandstones.*	*? Middle Eocene.*
Pangadi and *Kátéru Traps* and *Inter-trappean Limestone* (estuarine).	Deccan Trap series.	*? Lower Deccan Traps.*	*Upper Cretaceous.*
Dúdkúr Infra-trappean Beds, (marine).	Deccan Trap series.	*? Lametas.*	*Middle Cretaceous.*
Tripati sandstones (marine).	UPPER GONDWÁNAS.	*Umia Beds* of Cutch.	*Uppermost Jurassic.*
Rágavapúram shales (marine).	UPPER GONDWÁNAS.	*? Chari Beds* of Cutch, *? Jabalpur.*	*Upper Jurassic* (*Oxfordian* or *Callovia*).
Gollapili sandstones.	UPPER GONDWÁNAS.	*Rájmahál.*	Middle Jurassic (*Bathonian*).
Chintalpúdi sandstones.	LOWER GONDWÁNAS.	*Kámthi, Damúda.*	? UPPER PALÆOZOIC.
Bezváda gneiss.		Gneisses of the main or eastern region of the peninsular area.	AZOIC, CRYSTALLINE, or METAMORPHIC SERIES.

CHAPTER II.—GNEISS AND LOWER GONDWÁNA ROCKS.

The Bezváda gneiss.—Notwithstanding the more rapid and general survey of the area of crystalline rocks, enough was observed of them to justify the recognition of a particular variety or sub-division which other observers besides myself had noticed, more especially in the neighbourhood of Bezváda and on the Vizagapatam coast. It might be called *murchisonite* gneiss from the characteristic form of felspar entering so largely into its composition, which mineral was, however, eventually recognised by my colleagne, F. R. Mallet, in the specimens which were sent up to him for determination at Calcutta.

Previous knowledge of—

Dr. Heyne noticed the garnetiferous and felspathic constitution of the rock and its tendency to weather of a dark or even nearly black colour; writing of it: "Veins of felspar often run through this rock in oblique or horizontal direction. Such veins are much harder than the felspar, which enters as a constituent into the rock. * * * The felspar is white, foliated, and appears, when in large pieces, transversely striated. It is uncommonly soft, and is entirely disintegrated when long exposed to the air."[1] Dr. P. M. Benza describes,[2] but not in much detail, the garnetic gneiss of Bezváda, and he saw it again at Túni and other places in the Vizagapatam district; the felspar is specialised as albite or cleavlandite, and its beautiful scarlet red colour is noticed. He also refers to the easily-weathered character of the rock. Captain Newbold wrote—"The gneiss comprising the ridge of Bezwáda is garnetiferous, cleavlandite often replaces the common felspar, and renders the gneiss liable to decay. It contains large veins of quartz and is intersected by green-stone dykes, the presence of which may serve to account for the distortion observable in its strata."

Extent and relation to other gneiss.

A decided band of this garnetiferous felspathic gneiss edges the alluvium and older aqueous rocks right across the field, from the Kistna district into that of Vizaga-

[1] *Op. cit.* p. Tract XV, p. 230.
[2] *Op. cit.* p. 45.

patam. The Bezváda ridges and outlying hills are almost entirely composed of it, the only other strata being a few bands of quartz-schists and calcareous rocks, and thence to the north-east, in the Núna Stalum country, it has a width of some 16 miles and so continues occasionally narrowing or widening out into the Golgonda country. Alongside of it, on the north, there is the less schistose, or even more massive band of gneisses, stretching from the Kondapilli hills, which answers more or less to those of the Nellore and Kistna areas.[1] Indeed, so distinguishable is this form of gneiss in the area pointed out, that I gradually came to call it by the name here adopted; and the area occupied by it is so great that it seems quite worthy of being considered as a fair group among the gneisses of the main or eastern area of the peninsula. I am as yet unable to draw a clear line of demarcation between it and the gneiss on its northern side, but the tentative boundary given in the map shows its general limits. The dip of the foliation, or, as it is to all appearance, lamination, is generally high and to the south-east, though folding and contortion are frequent; and so far its later age over that of the Kondapilli gneiss, as evidenced by its less highly metamorphosed condition, is borne out.

Lithology.

With the exception of the thin subordinate bands of quartz-schist and quartzose gneiss, the usual rock of this band is generally of a dark brownish-red colour composed mainly of a bright, lustrous, well-cleaved, and occasionally foliated red felspar.[2] It is rough and granular, but well foliated or more or less schistose

[1] See Parts 1 and 2 of this Volume of the Memoirs.

[2] Mallet writes—"Your mineral is murchisonite, a variety of orthoclase, the distinguishing character of which is the presence of an abnormal cleavage, making (in the original mineral from Dawlish, in Devonshire) an angle of 106° 50′ with the basal cleavage and 90° with the clino-diagonal cleavage. These angles in your mineral are about 104° and 90°, or very near 90°. The lustre of Murchisonite on this abnormal cleavage is *pearly*, as in your specimens. The latter in fusibility, &c., have the characters of orthoclase. The hardness of the original murchisonite is rather less than that of felspar; that of your mineral is about 5·0. This low degree of hardness and the presence of free peroxide of iron led me to think that the mineral was in an altered state, but its translucency when looked at parallel to the pearly cleavage does not support this. It may have caught up the oxide when originally formed."

or even fibrous and then somewhat silky, though it is never quite a schist, or again tolerably massive. Sometimes the felspar predominates to such an extent that there are seams and even thick beds of what might be called a felspar rock, the murchisonite being then massive and granular. At other times, the rock is more like a granite with the felspar in largish crystalline masses; but usually when granitoid, it is a coarse granular aggregate of felspar, less quartz, and a little mica. Garnets are very frequently distributed through it, often to such an extent that it may be called a garnetiferous gneiss, as at Bezváda where the rock is often crowded with small crystals of bright red and purple colours which are only wanting in size to render them beautiful and valuable stones. Here also, and in the Augurpali country, there is a good deal of graphite thinly scattered through the rock, giving at times graphite schists or massive graphitic rock with the graphite in minute scales.

The felspar is generally reddish or a pale salmon colour weathering lighter, but it is frequently of a decided red, even rosy-red, and then, on well worn and smoothed surfaces it has somewhat the look of rhodonite while it has nearly always a fine pearly silvery or bright bronze sheen.

When weathered, the gneiss often presents, particularly in the Vizagapatam country, the most startling imitations of ferruginous sandstone, the garnets being so crowded together that there is a difficulty in recognising them as separate masses after they are decomposed. Even long before I took up work in this district, and at the time I was re-arranging the specimens in the Madras museum, my attention had been drawn to specimens from Bezwáda which were all labelled 'sandstones,' and yet were obviously part and parcel of other fragments from the same quarries which were unweathered *garnetiferous gneiss*.

Kámthi sandstones.—The remaining rocks of the floor are brown ferruginous, and variegated felspathic sandstones of this group of the lower Gondwána formation, which are strongly developed in the hill country to the east of Chintalpúdi whence they stretched away northwards into the eastern portion of the Nizam's dominions bordering the right bank of the Godávari river.

Mr. W. T. Blanford first identified these beds in this district, having traced them down from their typical area at Kámthi in the Central Provinces, and he describes them as "frequently variegated in a peculiar and characteristic manner. They are associated with numerous hard bands of ferruginous grit and compact red and yellow shale. In one instance sandstone was found with a peculiar semi-vitreous texture, which is very characteristic of some beds in Chánda and Berár. All these characters lead unmistakably to the conclusion that these rocks are the representatives of the Kámthi beds of Nagpur and Chanda"[1]

Traced down from Central Provinces.

At the same time, nearly half a century before either he or I worked at these beds, it had been pointed out by Voysey[2] that sandstones were traceable all the way down the Godávari valley from the Central Provinces into the coastal region of Ellore.

These sandstones occupy an old hollow in the gneiss, and are occasionally much more irregular and undulating in their lie than the beds of the upper division of the series overlying them, though, along the northern outcrop of the latter rocks, they lie easier and appear at times to be almost conformable with them. Like the rest of the gneiss country, the ground occupied by them is now at places very broken and irregular, as in the Chintalpúdi hills, where the curved and gradually assumed north-west strike, nigher and undulating dip, and great thickness of varied beds, give very different contours and slopes to those of the low long-backed ranges with north-western scarps of little height of the gently dipping strata of the upper Gondwána beds bordering the deltaic plains. It will be shown further on that the belt of these latter rocks lies evenly over these sandstones, and is so continued on to the gneiss to the east and west of them; or, in other words, that they are lying on a tolerably even plane of both crystallines and Kámthi sandstones. The Chintalpúdi hills do not, as far as I remember, show any of the unmistakable

Lie and association with the gneiss.

[1] Rec. Geol. Surv. of India IV, p. 49, *et seq.*, 1871.
[2] Jour. As. Soc., Bengal, Vol. II., 1833, p. 400.

flatly-denuded surfaces so characteristic of many of the hills in the gneiss country; but these could hardly be expected to have been preserved among such easily worn rocks, even if, which is barely possible, any of the old upper surface remain in these hills.

Fossils and their localities.

The fossil plants determining the age of these beds were obtained by Blanford at Somávaram, south of Núzvíd, and at Kunlacheru, 16 miles north of Ellore; fronds of *Glossopteris* at the former locality and *Vertebraria* at the latter. I subsequently obtained *Vertebraria* also at Somávaram, and other vegetable remains from fine pale dove-coloured compact shales a short distance south-east of the village at the bottom of a low scarped hill below soft coarse felspathic sandstones. On the west side and to the south of the village there are many wells, the debris from which consist of soft white and yellow clayey sandstones very coarse-grained, and in these were many fine specimens of *Glossopteris*, &c.

The number of fossils from the Kunlacheru locality was increased by finer specimens of *Vertebraria*, *Glossopteris*, and *Phylotheca*. Fragments of the first plant occur close to the village in a thick bed of compact splintery clayey sandstone, but the proper fossil locality is at the base of the 'Gut,' a small conical hill about 100 feet high to the west of the village. On the east side of this hill a tolerably fair section is exposed, all the rest of the slopes being covered with thick jungle.

Association of fossils.

At the base, about 10 feet of very coarse open-textured felspathic sandstones succeeded by 10 feet more of hard, very slightly calcareous fine clayey sandstones with fossils, over which come 20 feet of coarse beds like those at the bottom. Next come 6 feet of splintery silicious beds, overlaid by 40 feet of the coarse felspathic beds: all topped by a capping of nearly 20 feet of hard semi-vitreous ferruginous purple and brown sandstones and pebble beds belonging to the Upper Gondwánas. The beds are dipping about 5° eastwards. The fossiliferous band near the base is thus:

a. *Glossopteris* seam	2 feet
b. *Vertebraria* „	2 „
c. Splintery calcareous clayey bed	6 „

The *Glossopteris* seam is a fine sandy and clayey fawn-coloured rock, laminated and much easier broken up than the seam below. The *Vertebrariæ* are matted together but not very thickly, in the upper portion of the seam (a) which is very hard and splintery. Indeed, I had to leave some very fine examples of branched *Vertebrariæ* which could not be got out in any size without the rock splitting up into small fragments. The suggestion, I think, of Dr. Oldham, that the *Vertebraria* may be the root of some other plant, seems to gain some confirmation here through this association of them in this matted condition immediately below the *Glossopteris* bed.

CHAPTER III.—UPPER GONDWÁNAS.

The representatives of this series form the greater width of the low rather flat ranges of hills, with north-westerly escarpments, to the north of Ellore, extending with an east-north-east strike from Maléli to the right bank of the Godávari, near Thállapúdi. Beyond this break at the riverside no further traces of them are seen until the village of Jaggampet, on the high road from Rájahmundry to Vizagapatam, is reached, and then the series is only represented by a chain of outliers belonging to its higher group.

Grouping.

In the Ellore area the series consists of three groups, two of sandstones and an intermediate one of shales, which are exposed with more or less clearness on the slopes and scarps of the hills, the lower group forming a sort of foot or toe and the upper a low scarp and capping which slopes very gently down towards the alluvial plains. The groups are thus in tolerably conformable lie, with a low dip of from 5° to 10° or 15° south-eastward.

Extent and association.

The lower group is nearly continuous in its strike from Maléli, 16 miles west of Ellore, to within 5 miles of the Godávari bank; the middle one has only about a

third of this length of outcrop in the middle of the field; and this is again overlapped by the higher one, which extends from the Tammilér or Ellore river to within a short distance of the Godávari. The latter is also, as far as can be made out, continued on the Rájahmundry-Vizagapatam side of the country, but without any association with other sandstones, where it lies directly on the gneiss.

Fossils.

The three sub-divisions are fossiliferous at rare intervals; the lower only showing vegetable remains, whereas the other two give marine animals, one of them also having a few associated plants. The Gollapili sandstones, with their typically Rájmahál flora, have given one of the most definite geological horizons on the Coromandel, while the Rágavapúram shales and Tripati sandstones are brought into correlation by their marine fossils, the former with the previously-known fossiliferous patches of shales further south in the Nellore-Kistna area and at Sriperumbúdúr (Sripermatur) near Madras, and the latter with the Umia beds of Cutch.

Gollapili Sandstones.—About 12 miles west of Ellore, the large village of Gollapili stands on a series of dark-brown and yellowish-red sandstones grits and conglomerates which have yielded numerous plant remains of Rájmahál age. At the northern edge of the field, near Sómavaram, these sandstones are lying on, and overlap, other coarser but softer and more vari-coloured felspathic sandstones and sandy shales of Kámthi age, with the characteristic *glossopteris* and *vertebraria*.

Palæontology.

The fossils of these Rájmahál beds were found only at a few localities late in the progress of the survey; and as there is often a very close resemblance between these sandstones and those of the Kámthis, it was thus some time before I was able to separate this group from the larger area of rocks which W. T. Blanford had approximately sketched in as of the latter series during his preliminary traverse between Núzvíd and Ellore.[1] The complete collection was finally determined by Dr. Feistmantel, the palæontologist of the Survey,

[1] Records, Geol. Surv. of India, Vol. IV, p. 49; V., p. 23.

and subsequently described by him in the Palæontologia Indica,[1] from which the following list of fossils is extracted :—

FILICES.

1. *Alethopteris indica*, O. M.
2. *Pecopteris macrocarpa*, O. M.
3. *Angiopteridium ensis*, Schimp.
4. *Angiopteridium spathulatum*, Schimp.

CYCADEACEÆ.

a. ZAMIÆ.

5. *Ptilophyllum acutifolium*, Morr.
6. *Ditto cutchense*, Morr.
7. *Dictyozamites indicus*, Fstm.
8. *Pterophyllum morrisianum*, Oldh.
9. *Ditto carterianum*, Oldh.
10. *Ditto kingianum*, Fstm.
11. *Ditto distans*, Morr.
12. *Williamsonia gigas*, Carr.

CONIFERÆ.

13. *Palissya conferta*, O. M. sp.
14. *Ditto indica*, O. M. sp.
15. *Cheirolepis* comp. *munsteri*, Schimp.
16. *Araucarites macropterus*, Fstm.

With regard to this flora, Feistmantel says: "Taking the flora of the Rájmahál group in the Rájmahál hills as it has been partly described by Messrs. Oldham and Morris, and lately concluded by myself (*Pal. Indica*, 1876, contin., Pl. 36-48, pp. 53-110) as typical of that group, we find the flora of Gollapili to be a pure representative of it on the south-eastern coast of India."

"This local flora contains * * * most of the typical Rájmahá plants, the manner of preservation only being different. While in the Rájmahál hills, the rock containing the fossils is almost throughou of very hard consistence, and mostly of pale colour, the plants nea

[1] Flora of the Gondwána System, Vol. I, p. 163 *et seq.*

Gollapili are preserved in a fine-grained sandstone of red-brown colour; this rock is totally different from the former one, and yet belongs to the same group and includes the same fossils."

"The *Filices* are not very frequent, but all that occur bear exactly the Rájmahál character."

"As well as in the Rájmahál group of the Rájmahál hills, also here at Góllapili, the *Cycadeaceæ* are very well represented, except the genus *Cycadites;* but we find frequent *Ptilophyllum* and *Pterophyllum; Dictyozamites*, Oldh., also occurs."

"Remains of coniferous plants were found also pretty abundantly near Gollapili, as is generally the case in the upper portion of the Gondwána system."

Fossil localities and type area.

The plant remains were nearly all found near Ravacherla and Búravancha, 6 miles west of Gollapili, in softish brown and purple sandstones, there forming three low and south-eastward sloping terraces with low scarps to the north-westward. These beds are very near the bottom of the series—in fact just above a thin set of bottom beds, the village of Ravacherla itself being on the garnetiferous or Bezváda gneiss. Other, but very fragmentary, remains were found further north, around Músunúr, in a set of soft micaceous shales and flags of much finer texture than the Ravacherla beds, which are even lower in the series, there having been a thickening out of the strata towards Núzvíd. Gollapili is on still higher beds, but it is the largest and most important village in the field; hence its name has been given to this group.

Thickness.

The group is not of much thickness, seldom at its thickest more than 300 feet. At the Gollapili end, the beds are lying in a shallow basonal way, with a low rise to the north-westward; and from this area they are continued to the east-north-east in a long outcrop at the foot of the scarps, striking past Tandkalpúdi, Tripati, and Rágavapúram to Bimúlú, some 5 miles from the right bank of the Godávari, where they die out altogether and are overlapped by the Tripati sandstones.

For nearly the whole outcrop there is a tolerably persistent form of bottom beds, namely, a very hard, compact, sometimes semi-vitreous or again jaspideous, red ferruginous clayey sandstone, grit, or conglomerate. The sandy and gritty particles are frequently of clear glassy quartz, and sometimes, when the rock is vitreous or jaspery, these are scattered through a kind of paste and give the rock a semi-igneous look like a dark-red quartz porphyry. This jaspery or vitreous form is well seen in the low scarps of the Núzvíd area to the south of Sómavaram, or at Rámakapeta; or, again, it is common some 12 miles eastward of the Ellore area to the south of Kunlacheru there capping the two outlying hills, called '*guts*,' and the scarps behind them. Further east of this, as below Tripati and the Rágavapúram outlier, the group is represented by coarser dark-brown conglomerates and grits, still hard and vitreous, but not so clayey or jaspery.

Persistent form of bottom beds.

At the Núzvíd end, the western boundary between Ravacherla and Sómavaram is, in part, faulted or crushed against the gneiss; the beds being curved and sharply tilted up along this line, especially opposite Rámakapetta, while they are also much jaspidified and infiltrated with quartz. The lie of the strata at Ravacherla is, however, quite easy, at least to within a short distance of the gneiss, the contact being covered up by debris; but if there be no fault here, then the lower heavy conglomerates and hard jaspery clayey sandstones are overlapped by the higher beds containing the plant remains. The more reasonable supposition is, that faulting has extended along here, and that higher strata have thus been brought directly alongside the gneiss. At the same time, the boundary is not faulted for its whole length, some outcrops not being squeezed or altered in any way, for instance, it is quite natural just south of Núzvíd, where the gneiss is covered by easy-lying beds.

Lie.

At a very short distance from the western edge, the strata become nearly flat again and dip easily under fine micaceous sandstones, which occur in good force in the small group of flat-topped hills to the south of Akreddigúdem. These

Succession of strata.

are from 80 to 100 feet high and are made up of thin, fine, soft micaceous sandstones and sandy flags of buff and purple colours, while about 20 feet at the summit is of thick-bedded, coarse, soft, micaceous, brown weathering sands. The Músanúr valley is altogether of the lower beds, which dip gently to the southward, under the Ravacherla beds, the lowest of which must correspond to those capping the hills just referred to. These are succeeded by about 50 feet of thinner, generally rather coarser and more variegated, sandstones, with a few yellow and red clays, never so micaceous as the Músanúr beds, over which comes a thin band of hard brown sands, giving a low head-land and scarp near Pólsanpili. Then come some 30 feet of lighter-coloured sandstones on which Gollapili is situated, succeeded by about 100 feet of massive thick-bedded, dark-brown micaceous sandstones in the long rounded slopes below the Dúdúgut scarps. The latter sandstones weather of a dark-brown purple colour, in smooth rounded humps which stand out in the jungle very like humps of gneiss.

This succession may be put thus in tabular form:—

f. Massive brown micaceous beds below Dúdúgat scarp . .	about	100 feet.
e. Light-coloured variegated sandstones of Gollapili itself . .	„	30 „
d. Pólsanpili headland beds	„	10 „
c. Softer and lighter-coloured sands; and, lower, the brown fossiliferous beds of Ravacherla	„	50 „
b. Músanúr micaceous beds	„	75 „
a. Bottom beds, indurated clayey sandstones, &c.	„	20 „
	About	285 feet.

These thicknesses vary a good deal; but the total here given is about the greatest thickness there can be of the whole group.

This succession in the Núzvíd basin is more properly a local assemblage of varied strata, for it does not extend, or is not represented, beyond the Tammilér side, except by the bottom indurated clayey sandstones (*a*), and by the massive micaceous beds (*f*), which are continued in the low jungle-covered hills north of Víjarai.

Thinning out and denudation.

These Víjarai hills show no capping of other sandstones and conglomerates as in the Dúdúgut range, though to the south-east at Nayanapalem and near Tundkalpúdi there are again sandstones rising into very low scarps, between which and the jaspideous conglomerates and sandstones coming out from under the Víjarai strata is only a slight thickness of beds to represent such a thickness as is in the Víjarai hills; hence it is quite clear that the Gollapili series must have thinned out, or have been much denuded, to the eastward of the Tammilér river.

The bottom beds (*a*) hade out from under the sandstones of the Víjarai hills in the Kunlacheru valley, and there form a skin over the Kámthi sandstones of Kámarapúkota, whence they continue to the east-north-eastward, essentially a set of dark-brown and reddish, hard, ferruginous sandstones, and heavy conglomerates and stony clay beds, now thickened out to some 50 or 60 feet, and quite unfossiliferous.

It certainly seemed to me that there must have been great denudation of the whole group, though no doubt there was also thinning out to the eastward, prior to the deposition of the succeeding group next to be described.

Unconformable to Kámthis.

The unconformity of the Gollapilis on the Kámthis is very evident on the whole, but I cannot point to any section showing this directly. Around Kunlacheru, the lie of both series is very flat, and the bedding of the very coarse friable felspathic sandstones of the older series is very obscure or much covered up by debris; still the hard, heavy, vitreous, and jaspery conglomerate, and claystones are lying evenly over a planed down floor of different sands, and not over a bed or band of beds of these. Towards Kámarapúkota this is more evident, and to the north and east the strike of the Kámthis begins to curve round from north-east to the north-west run which it has in the Chintalpúdi hills. A feature connected with the decided change from one to the other series along their boundaries is the remarkable difference in the quality of their debris. Of course, the detritus of both is for the most part sand; but that of the Kámthis is

remarkably harsh, coarse, and, if anything, lighter coloured, though there is a good deal of ferruginous matter in them also. I got so used to this difference in the feel of the sandy ground after passing and re-passing across the boundary for many days, that I could note the change very soon as my feet fell on the harsher and coarser debris. The debris is also often gravelly, and much of the gravel is made up of small pieces of hard stony clay and buff cherty material which is not often met with in the upper Gondwánas. The ferruginous matter of these last is also I think, on the whole, more evenly distributed through the beds: in the Kámthis it is oftener distributed in seams, knotty and warty segregations, and surface infiltration.

Rágavapúram shales.—These and their fossils were first noticed in the side of a small flat-topped hill, a short distance east of Rágavapúram, about 28 miles west-by-north of Rájahmundry. They are generally very fine-grained, rather unctuous, shaley clays and clayey shales of white buff and lilac colours, laminated, but not very easily split up in the planes of lamination, and breaking up easiest across the bedding in clunchy sub-angular lumps having a rude conchoidal fracture.

Lithology.

The group does not, however, consist entirely of shales, but contains several seams, of more or less strength and persistence, of sandy beds at different levels, none of which are ever strong enough to take away its decidedly shaley facies. There are altogether about 100 feet of shales themselves at the thickest, the whole series never exceeding about 160 feet; white and buff towards the bottom, purple and buff in the upper half. Among the shales there are three or four thin beds of greenish-yellow sands, soft and friable but rather hard at the outcrop, with brown ferruginous coating. These thin seams are each usually about 9 inches in thickness. The shales are much seamed with brown ferruginous matter in east-west joint planes, and in other minor fissures by infiltration. Some of the smaller fissures and the exposed surfaces of these are also coated with a bright sulphur-yellow ferruginous deposit.

The outcrop shows for about half the length of the run of the north-

western slopes of the Tripati range of hills as a thin lenticular band for a length of some 16 miles, from the village of Dávanavárgúdem to within a short distance of Yádavol where it thins out, so that the over and underlying sandstone groups come into superposition.

A lenticular band between the other groups.

There has been a good deal of local slipping or faulting in the outcrops near Rágavapúrum, which, I think, are in great part of quite recent date. At first sight the succession of the beds here is rather obscure, especially in the small hill east of the village, where a well-marked but thin sandstone band occurs in several stepped outcrops along the steep northern slope, but without any corresponding breaks in the coarse sandstones capping the plateau. It appeared to me that this series of step throws might be entirely due to occasional slips or slides of these same slopes which are very apt to give way owing to the clayey character of the rocks.

Local and recent disturbance in outcrops.

At certain levels the series is crowded with marine shells of a few genera, with which, however, are occasionally associated rare vegetable remains. The commonest fossil is the cast of a *Leda,* which is nearly always much crushed and distorted; it is specifically undeterminable.

Marine organisms.

Dr. Feistmantel[1] has determined the plants and some of the animal remains; and he writes—"These beds overlie those of Gollapili, the flora of which has been also already described as the representative of the flora of the true Rájmahál group. The flora of the Rágavapúram shales is of a somewhat different character, containing some forms common to the lower beds; and also some others, which are Jabalpur plants, or at least closely related to them."

Fossil plants.

"The plants of the Rágavapúram shales are—

Pecopteris reversa, n. sp. The same form was also found in the Sripermatur group (Sripermatur area).

Angiopteridium (*Tæniopteris*) *spathulatum,* Schimp. (McCl., sp.), Occurs in various

[1] Pal. Indica: Gondwána Flora, Vol. I, p. 191 *et seq.*

forms in the Rájmahál group and in the Sripermatur group. Known also from the Gollapili beds.

Angiopteridium mc'clellandi, Morr., sp. A Rájmahál plant.

Pachypteris ellorensis, n. sp. Peculiar to the Rágavapúram shales.

Pterophyllum, sp.? Fragment of a leaflet.

Podozamites lanceolatus, L. & H. Occurs in the Jabalpur group.

Otozamites abbreviatus, Fstm. Is a Rájmahál plant.

Ptilophyllum acutifolium, Morr. A common form in the Rájmahál group (also at Gollapili).

Taxites tenerrimus, Fstm. A Jabalpur plant.

Taxites planus, n. sp. Occurs in the Sripermatur and Nellore-Kistna areas, more numerous in the former.

Gingko crassipes, Fstm. Occurs also in the Sripermatur group (Sripermatur area). Another species of this genus is known from the Jabalpur group."

"This list shows that the flora cannot be well taken as the representative of the Rájmahál group proper, and as the shales of Rágavapúram overlie the Gollapili beds (true Rájmahál group), the flora of the former may be considered of somewhat younger date.

"Besides the plants there are some animal remains, amongst them a form of *Ammonites*, which is also found in the Sripermatur group, and in the shales from the Nellore-Kistna district; then *Leda*, *Mytilus*, and some others, which are ill-preserved and can hardly be determined specifically, and a specimen which can hardly be distinguished from *Trigonia interlævigata*." [1]

The other remains found were—

Fish scales (cycloid)? 2 sp.
Ammonite (a further species).
Solen.
Tellina.
Pecten.

Besides these,—these are very common,—some strange, flat, straight, or sometimes slightly curved tubiform bodies from 1 to 2 or 3 inches

[1] For Feistmantel's references to Sripermatur and Nellore-Kistna, see Foote, Memoirs Geol. Surv. of India, Vol. X, pt. 1; Vol. XVI, pt. 1; Records Geol. Surv. of India, Vol. XI, p. 156, *et seq.*; also Manual of the Geology of India, pt. 1, pp. 149, 247.

in length and a quarter of an inch broad, tapering slightly from one end to the other, having very narrow closely-packed folds or plications transverse to their length, about which folds numerous foraminifera are impacted.

There is no enclosing case to these bodies, and from their form they appear to me to be of the nature of excrementitious discharges of some animal.

The succession of strata, exposed on the north side of the outlying hill near Rágavapúram, is as follows :—

Order of strata.

At the bottom of the slope and some distance out from it, the underlying dark-brown and nearly black ferruginous sandstones and conglomerates of the Gollapili group form a narrow terrace. Then all is obscured by the debris from the shales and sandstones of the hill for a good width ; indeed I do not think the junction is anywhere clearly exposed along the foot of the whole range of these low hills.

Thick bands of shales.

Good measurements could not be made on such broken slopes, the local slipping having been very strong on this hill-side, but the following approximate thicknesses are given. The lower half (about 60 feet) of the hill is of fine white and buff shales, which towards the top become coarser and more sandy. At 40 feet there is a fossiliferous zone about 6 feet thick, with greenish-yellow sandy seams containing the smaller of the two *Ammonites* and nearly all the other shells named.

A tolerably persistent seam, about 1 foot thick, of hard sandstone succeeds the 60 feet of shales, and over this come reddish and brownish sandy shales, with *Ptilophyllum*, &c., *Tellina*, and the larger *Ammonite*, for about 3 feet.

Next come about 53 feet of pale (brown weathering) very fine sandy shales, which again towards the top become coarser, more sandy and rough to the touch, with purple spots and blotches, in the middle of which are occasional *Ledas*, *Pectens* and the tubiform bodies with foraminifera.

Over these are 30 feet of lighter-coloured (nearly white), purple-blotched ferruginous sandy shales, having 4 or 5 feet of soft white clayey shales at the top.

Clay-ironstone band.

On the top of these is a 3 feet band of ferruginous dark-brown red yellow and purple sands and clays, with seams of flat oval clay-ironstone concretions and irregular segregations having very hard and ferruginous cores, which is again succeeded by 10 feet of the soft white clayey shales. This clay-ironstone band is fairly persistent throughout the shale exposure.

About 4 feet of softish irregularly vesicular lateritoid clayey sandstones then succeed the soft white shales, and are in their turn capped by the semi-vitreous gravelly beds of the Tripati group.

The dip is very low, seldom more than 5° to 8° to the south-east.

This succession is seen for some distance round the slopes towards Unnamalanka and to the south of Rágavapúram. South-westwards, in the direction of Komera, the clay-ironstone band is strongly developed, though the whole group is gradually becoming thinner, and the slopes are profusely covered with fragments of the concretions some of which are very large, 3 to 6 feet long. The shell of these is generally of innumerable fine concentric laminæ of brown, yellow, red and purple colours, the core being of a brilliant red colour, or, as often, dark purple; many fragments being also seamed with infiltrations of gypsum. I failed to find any organism in them. The ironstone band is continued to the west-south-westward, beyond the limit of the shale member of the group under the Tripati sandstone of Dávanavárgúdem.

Section below Tripati scarps.

A further good exposure of this group, though the shales are not now so well developed, occurs in the slopes below the scarps of Tripati, which are very much covered up by the debris from the sandstones and ironstone band above. The following section is made up from measurements taken not very distant from each other, commencing at a pot-hole in the small *nala* a short

distance north-east of the village, where beds of the Gollapili group are exposed :—

Tripati beds.	
Shales ... ... about	20′
Concretionary clay-ironstone band	6′
Fine clayey shales, grey; purple paper shales	34′
Pale grey lilac shales, or soft unctuous shales with thin and irregular seams of grey and yellow sandstones, very variable	2′
4 to 8-inch flaggy beds of pale brown sandstone passing up into a 6-inch seam of thinner and more ferruginous brown and purple layers	2′
Soft and purple reddish sands	3′
Hard brown sandstone	0′—6″
Fine-grained hard brown sand	0′—3½″
Thick and thin-bedded white laminated yellow and pale buff fine soft sandstone	9′—6″
(Blank, junction not well seen for a foot or so).	
Fine-grained soft purple sandstones mottled with round spots and kernels about the size of peas, of nearly black ferruginous matter	7′—3″
Grey and purple soft vesicular-looking or porous ferruginous sandstone	1′ or more.
Gollapilis; coarse pebbly ferruginous sandstone, about 3 feet exposed.	

No fossils, except a few indistinct fragmentary plant remains, were found here.

The lie of the beds is rather flatter than at Rágavapúram, but there is at times a good deal of undulation, which, however, is in part due to slipping of the strata on the slopes.

Here there is little correspondence with the Rágavapúram section, except in the thick band of shales, now much lessened, and in the stronger development of the ironstone band. The beds below the shales are very variable, and they are not constant for any distance, showing that they are, in fact, bottom beds of a series.

There is no large exposure of the mode of superposition of this shale series on the Gollapili beds. Where the junction is seen, they are always lying on hard ferru-

Relation to Gollapili group.

ginous sandstones and conglomerates which it would be very difficult to distinguish from each other, though it did appear to me that below Tripati they are lying on an undulating surface of these—not necessarily a denuded one—which is overlapped by different beds of the lower part of the group, but still to such an extent that this could not be called a case of local false bedding.

Very different rocks.

The group is, however, remarkable in its lithological constitution, and is thus eminently separable from the underlying sandstone series, irrespective of its much smaller extent; and this character or condition offers ground for the conclusion that a decided interval of time must have intervened between its deposition and the conclusion of the period of sandstone formation. The material deposited and the remains of animal life are altogether different to those of the lower group, though there are still two of the vegetable forms common to both.

Indication of separation of groups.

The interval may represent a period of gradual depression, during which the area became too distant from the receding shore line to be within the range of coarse arenaceous deposition such as had been deposited in the Rájmahál period. Under these new conditions, the bottom was then more likely to be covered by the finer sediment only, containing shell remains with a pelagic facies generally making up the Rágavapúram strata, the few plant remains having been floated out to sea.

Tripati sandstones.—The very low scarped edge crowning the south-western slopes of the Tripati range is made up of these beds, and their outcrop is continued, but with a less constant lithologic facies, to the right and left, dropping down to the hollows of the streams crossing the range, and rising up again in less elevated prominences until it finally shores up against the Gutalla gneiss ridges on the right bank of the Godávari, or sinks down under the narrow alluvial strip of the Tammilér to the north-north-west of Ellore.

There are many places where this group of sandstones is well and conspicuously developed, but a good and notable headland of them

overhangs the well-known temple of Tripati,[1] some 23 miles north-east of Ellore and 28 west-by-south of Rájahmundry; and the name of the group is so taken.

Thickness.

In no section is there a fair idea given of the thickness of the series, the scarp only showing some 40 or 50 feet at the most of the lowest strata. From the scarp there is a long slope down to the south-east, on which little can be learnt of the upper beds; but wells are sunk at two or three points, to a depth sometimes of nearly 70 feet, and these do not appear ever to have touched the lowest or scarp beds, so that at a rough calculation the whole thickness cannot be taken at more than 150 feet, if indeed it can be so much, and from personal observation I can only write off 120 feet of this.

Lie.

The lie of the beds is from 5° to 10° south-east; perhaps they may, on the whole, dip slightly more to the eastward of this and may be flatter than the Rágavapúram beds.

Lithology and succession.

The lower portion, or the scarp beds, are often scarcely to be distinguished from the bottom Gollapili beds; indeed, it may also be said that they are frequently just as undistinguishable from the much newer Rájahmundry sandstones. They are essentially a set of dark-brown and reddish sandstones, gravel beds, and conglomerates, with bands of highly indurated or vitreous siliceo-argillaceous beds of the same kind and concretionary clay-ironstones. They are rather softer and more varied in colour towards the bottom, becoming harder and more ferruginous higher up; and it is these harder beds which make up a good deal of the Nullacherla and Yernagúdem country leading down to the delta lands. Much of the hardness of the upland rocks is, however, due in great part to weathering, these heavy ferruginous sandstones and conglomerates having a wonderful tendency to assume a lateritoid character on exposed surfaces.

[1] This is Chinna, or the 'smaller' Tripati, and only inferior as a place of pilgrimage to the more famous and larger Tripati, in North Arcot, the most sacred temples of which are above a far grander scarp of quartzites of the upper transition series.—*See* Memoirs Geol. Surv. of India, Vol. VIII, pp. 18, 177, 179.

Nevertheless, there are undoubted hard and vitreous bands and beds which owe their induration and jaspery condition to other than mere weathering forces, which are properly characteristic of the group.

Such is the style and condition of the first 40 feet of the group in the greater part of the length of the outcrop, that is, between Dávanawárgúdem and Yádavol. Beyond the latter place the beds are generally softer and freer ferruginous sandstones, still of the usual dark-brown and reddish colours. To the south-west of Dávanawárgúdem there is quite a change in the character of the beds, which will be referred to immediately.

Above the scarp beds is a set of somewhat softer and more variegated freer sandstones which are only known by the few wells between Unnamalanka and Yernagúdem.

A few poor and unrecognisable vegetable remains, such as fossil wood, probably coniferous, were all that could be found; and these are always in the softer beds between Yádavol and Annadávarupád.

Variations in members of group.

To the south-west of Dávanawárgúdem, the hard ferruginous or scarp beds thin out under the low scarp to the south of Tundkalpúdi, and are very little separated from the heavy ferruginous beds of the Gollapilis, which are here locally the 'Gut' beds of Sanáshi and Kunlacheru; and they are more or less recognisable as far as the left bank of the Tammiléru. The upper softer variegated beds are replaced by a set of strata in the scarp which are quite different to the usual style of beds in the three groups, with the exception of some of the Kunlacheru beds, the resemblance to which is such that W. T. Blanford[1] was very naturally in the preliminary survey led to suppose that they belonged to the Kámthi series.

These new beds begin to show in the jungle to the west of Dávanawárgúdem, south of Tripati. Yellowish-brown laminated felspathic sandstone, the sand fine or not easily distinguishable, more properly a fine clayey sandstone with frequent seams of white clayey fragments

[1] Rec. Geol. Surv. of India, Vols. IV, p. 49, V, p. 28.

or galls; also highly ferruginous brown and purplish indurated clay and hard sandstone, with seams and patches of grey iron-ore granules.

Tundkalpúdi beds.

At Tundkalpúdi scarp itself, the strata are hard, compact, rather fine-textured yellow sandstone and pebbly beds. The thick beds of yellow sandstone are often so compact hard and vitreous that they are more like coarse jaspery beds. There must be about 100 feet of these yellow beds, but they are very irregular in their separate thicknesses, swelling out considerably at times while they and the pebbly beds shade into each other.

Under the yellow beds are more variegated and various sandstones, with a thin band of dark-brown ferruginous sandstones the particles of which are coarse and like rice grains of quartz.

The yellow beds give a very favourite building stone in this part of the country, one thick bed of 10 feet having been opened up by two large quarries.

Peddavegi beds.

Further south-east, the yellow beds of the Tundkalpúdi scarp have been denuded in the Náyanapalem stream, while the underlying variegated beds show in better force; and among these is a band of bright-red (often vermilion red with occasional white and yellow blotches) fine-grained sandstones which are quarried about a mile north-east of Peddavegi, and are well known all over the Ellore side of the country having been largely used in the canal works there. Close to the left bank of the Tammilér, fine compact yellow sandstones are quarried at the village of Janampet which must belong to the same group, though I think they are not of the Tundkalpúdi band.

Cut off at the Tammilér.

On the other side of the river, there is no further sign of any sandstones answering to those of Tundkalpúdi: the change is abrupt and remarkable, to a series of dark-red, brown, and nearly black ferruginous conglomerates and sandstones which lie directly on the gneiss and then run up to the north-west as the long slopes of the low Dúdúgut range.

The disappointing feature about these sandstones of the Tripati

and Tundkalpúdi scarps is that they have not as yet yielded any recognizable fossils, while their abrupt finish at the river banks limits their identification with other sandstones in the field. However, some 24 miles away to the north-east of Rájahmundry, at Jaggampet, coarse ferruginous sandstones and conglomerates are lying directly over a sloping floor of gneiss; and beyond this, smaller and smaller patches of these occur near Kirlampúdi, Ayaparáz-Kotapili, Paidikonda, and to the east of the Srirámpúram, one of which has yielded fossils of Umia (Survey classification) or upper jurassic age. These sandstones are, in many respects, very like those of either the Gollapili, Tripati, or even the Rájahmundry zones but they are, on the whole, more like Tripati beds, and their upper jurassic age favours this correlation of them.

Represented in the Vizagapatam country.

At Ayaparáz-Kotapili (24 miles north-east of Cocanáda, and 4 miles east of Bendapúdi, on the Rájahmundry-Vizagapatam road), a low ridge rises out of the alluvial flat on the south side of the village. This is of gneiss overlaid by very coarse ferruginous indurated clays and conglomerates, which are succeeded by a set of fine thick and thin-bedded grey and purple sands, with a few clay-ironstone concretions, containing a few fossil shells.

Fossiliferous beds of Ayaparáz-Kotapili.

The beds are dipping about 8°—10° south-south-west, and the ridge may be about 40 feet high at the eastern end.

The fossil bed is thin, a coarsish soft muddy sandstone of a purple color, ferruginous, full of fragments of shells, which, from their ferruginous constitution, break up very easily and fall to dust. It runs along about half-way up the ridge between pale yellow and buff, and pale purplish sands, soft and fine-grained, largely made up of concretionary masses with hard purple sandy cores. Occasionally, fossils are seen on a hard brown surface of some of the sandstone beds.

The finer and more compact beds are overlaid by very coarse-grained hard ferruginous sandstones of little rounded particles of clear semi-translucent quartz, with occasional small pebbles of white quartz and clay.

I obtained the following fossils, which were hastily determined by the late Dr. Stolickza just before he left Calcutta on his ill-fated journey to Yarkand:—

Marine fossils.

Belemnite,	*Inoceramus*,
Ammonites,	*Pseudomonotis*,
Helicoceras,	*Lima*,
Trigonia ventricosa (Krauss),	*Pecten*,
„ *smeei* (Sow.),	*Fossil wood*, ? coniferous.

Dr. Stoliczka considered that these fossils showed their beds to be the equivalent of the Umia beds in Cutch, which are of uppermost jurassic age: and since, on physical and lithological grounds, it seems very probable that these beds are on the same horizon as the proper Tripati beds, it is for the present presumable that this group is of like age.

Uppermost jurassic age.

We have thus, as representatives of the Upper Gondwána series on this part of the Madras coast, three groups of rocks clearly distinguishable from each other by their superposition, lithological constitution, and fossil remains, though they are not so clearly separable by undoubted denudation, the stratigraphical breaks showing, rather, intervals of ordinary depression and elevation.

General conclusions.

At the same time, had there been no fossil remains, I do think that the lithological differences and the different extent of the three groups would have attracted more notice than W. T. Blanford[1] is inclined to suppose, for we had already become acquainted to the south with the patches of shales at Sriperumbudur (Sripermatúr), and in the Trichinopoly, Nellore, and Kistna districts; while I do not myself recollect any case of so distinct a set of beds in all the vast area of Kámthis extending from Chintálpúdi right up the valley of the Godávari to the Central Provinces. On lithological grounds alone,

[1] *See* Manual of the Geology of India, p. 149.

I should have distinguished the present beds as three groups in the area between the Godávari and the Tammilér; and I should certainly have been inclined to look on the whole series as very possibly represented by some of the Rájmahál beds to the south.

The want of evidence as to strong stratigraphical breaks, though a great loss, is, as will be seen later on, common more or less to the whole series of formations in this area, from the Rájmaháls of Gollapili up to and including the Rájahmundry sandstones, which represent a period ranging from, say, middle mesozoic times up to middle eocene; for there is no greater show of unconformity—except by overlap—between the Tripati sandstones, the infratrappeans, the traps and intertrappeans and the Rájahmundry beds, than there is between the groups now in question.

There is, however, the lithological difference, there is also overlap, and, as I have endeavoured to show, there is some ground for looking on the Rágavapúram shales as overlying an unevenly worn surface of the Gollapili group—in fact, that the latter are perhaps more separable from the former than these are from the Tripati beds.

The fossil evidence, as far as it goes, is tolerably decisive as to the separation of the groups. Only two plants of the Góllapili beds occur in the Rágavapúram shales; and there is the entirely new feature of these shales being distinguished by a marine fauna. Of course, it is quite possible that the Gollapili beds may have been deposited in salt-water, or rather, close to the shore; but considerable changes must have taken place in the area of that sea and the adjoining land before the shales and their pelagic remains could have been deposited. In the succeeding group there are no recognisable plant remains; but its representative at Ayaparáz-Kotapili is remarkably distinct in the facies of its fauna, which has two fossils, *Trigonia ventricosa* (very common) and *T. smeei*, which are common to the Umia beds of Kutch; and its beds, like those at the eastern extremity of the Tripati outcrop, are lying directly on the gneiss.

CHAPTER IV.—DECCAN TRAP SERIES.

Trap scarps of Rájahmundry, &c.

In the neighbourhood of Rájahmundry and on the opposite side of the river, further ranges of low hills, with scarps to the north-north-west and long south-eastward backs, of sandstone and other rocks, form the first fringe of rising grounds edging the alluvial flats. The escarpments and their lower slopes have long been known for their trappean outcrops which display on both sides of the river interbedded fossiliferous limestones, and on one side (the western) are underlying sets of beds also containing numerous fossils.

Long known.

On January 30th, 1835, Dr. P. M. Benza, while travelling in this district, visited the western or Pungadi region in company with Colonel Cullen who had told him that he would here meet with "shell limestone underlaying and alternating with basalt."[1] I have been unable to find any record of Colonel Cullen's observations on these beds, for he had evidently become acquainted with them in previous years; but he was at any rate right as to there being an infra-trappean set of beds, as well as an intertrappean outcrop. It is not at all clear from Benza's paper whether he did see these underlying rocks, but he does not distinctly mention them; and he appears to have misunderstood the position of the Rájahmundry sandstones which have, somehow or other even by subsequent writers, been considered as subjacent to the traps. Otherwise, Benza's paper is an interesting record of the early knowledge of this so distant and isolated an outlier of the Deccan traps on the eastern coast. He does not offer any opinion as to the age of the fossiliferous beds.

The locality near to Rájahmundry does not appear to have been brought to notice until 1854, when Mr. Walter Elliott, of the Civil Service, sent a collection of fossils from Kátéru to the Asiatic Society of Bengal, with notes[2] thereon. He shows that the Kátéru limestone crops up between flows of basalt, but offers no comment on the age of

[1] Madras Journ. Lit. and Sci., 1837, Vol. V, pp. 50—53.
[2] Journ. As. Soc., Bengal, Vol. XXIII, p. 399.

the rocks, further than that the trap is of the same kind as that he had observed in the Deccan.

However, this region had not long to wait after this for thorough scientific treatment, for in 1855—1860 the Rev. Messrs. Hislop and Hunter issued papers[1] treating incidentally of this region.

Worked out by Hislop.

Hislop's last paper is mainly taken up with the traps and intertrappeans in the neighbourhood of Nágpúr; but there is a good description of the Pungadi and Kátéru rocks, and nearly all the fossils which have been found up to this time in the intertrappean beds are described and figured. He is strongly of opinion that the trap underlying the limestones is newer than that above,—in fact that it is an intrusive sheet; and I must say that, though he did not see the rocks here, there is rather more apparent evidence about them for this view than what he offers for the Nágpúr outcrops. Of the age of the Godávari rocks and their fossils, he says,—"From all these facts, I am disposed to deduce the inference that our intertrappean or subtrappean deposits belong to the lower eocene;" and this may be true for the intertrappean beds, at any rate, though, as will be seen further on, there is some evidence towards ranging them rather lower than this in the geological scale, even to the possibility of their being of intermediate age between the secondary and tertiary periods; while the infra-trappean beds appear to have upper cretaceous affinities.

The succession of rocks in the whole series of traps and fossiliferous beds in the Pungadi region, where it is also most perfect, is, in descending order:—

Grouping.

Basalts	
Fossiliferrous limestones	*Inter-trappean.*
Basalts	
Fossiliferous limestones and calcareous sandstones ...	*Infra-trappean.*

At Kátéru, there are only the upper and lower traps, with an intermediate band of fossiliferous beds.

[1] Quart. Journ. Geol. Soc., Lond., Vols. X, p. 1655; XI, p. 365; and XVI, pp. 154—166.

Fossils.

In addition to the specimens obtained by me, a large collection was sent up to the Calcutta Museum in 1876 by Mr. A. J. Stuart, then Sub-Collector at Rájahmundry; and these, including the large number of fossils described by Hislop,[1] give the following list:—

INTER-TRAPPEAN.

Pangadi and Kátéru.

GASTEROPODA.

Fusus pygmæus, Hislop.
Pseudoliva elegans, Hislop.
„ sp.
Natica stoddardi, Hislop.
„ 2 sp.
Cerithium multiforme, Hislop.
„ *subcylindraceum*, Hislop.
Cerithium leithii, Hislop.
„ *stoddardi*, „
Vicarya fusiformis, „
Turritella prælonga, „
Paludina, sp.
Physa prinsepi, Sow.
Dentalium, sp.

PELECYPODA.

Ostrea pangadiensis, Hislop.
Anomia kátéruensis, „
„ 2 sp.
Lima, sp., Hislop.
Perna meleagrinoides, Hislop.
„ 2 sp.
Modiola, sp., Hislop.
Arca striatula, „
Nucula pusilla, „
Lucina parva, „
„ *(Kellia) nana*, Hislop.
Corbis elliptica, Hislop.
„ 2 sp.
Corbicula ingens, Hislop.
Corbicula, 2 sp.
Cardita variabilis, Hislop.
„ *pusilla*, „
Cytherea orbicularis, „
„ *wilsoni*, „
„ *wapsharei*, „
„ *rawesi*, „
„ *jerdoni*, „
„ *elliptica*, „
„ *hunteri*, „
Tellina woodwardi, „
Psammobia jonesi, „
Corbula oldhami, „
„ *sulcifera*, „

INFRA-TRAPPEAN.

CRUSTACEA.

Chelæ of crab. (These are very numerous, but they are the only remains of the crab.)

CEPHALOPODA.

Nautilus, sp.

[1] Op cit.

GASTEROPODA.

Rostellaria.
Murex.
Fasciolaria.
Latirus.
Pyrula.
Fusus, 2 sp.
Buccinum.
Pseudoliva.
Pleurotoma, 2 sp.
Volutilithes.
Natica.
Turritella, 2 sp.
Dentalium.

CILIOPODA.

Lunulites.

PELECYPODA.

Ostrea.
Cucullea.
Pectunculus.
Corbis.
Cardita variabilis, Hislop.
" ? 3 sp.
Cytherea.

Out of all these, only one, *Cardita variabilis*, is common to the inter and infra-trappeans. The latter are clearly marine, in contradistinction to the Pungadi and Kátéru beds which are estuarine.

Infra-trappeans.—The lowest beds associated with the traps occur at the base of the northern slope and along the western half of the Pungadi range of hills, 12 miles to the west of the right bank of the Godávari, where by their position they succeed the Tripati sandstones of Yernagúdem. They consist of a series of sandstones, calcareous towards the top, with an upper seam or crust of fossiliferous limestone. These strata are more or less exposed at three points along their outcrop, namely, a little south of Gowripatnam, at their eastern end; again on the road from Pungadi to Dúdkúr, about a mile before reaching the latter village; at Dúdkúr itself, and a little south of it; and again at a point near Devarapili, at the western end of the outcrop. From end to end the exposures indicate a length of about three and three-quarter miles.

Thickness.

The greatest thickness ascertainable occurs at Dúdkúr, where there are 48 feet of sandstones, &c., and the lowest beds are not exposed, a good width of ground between these and the Yernagúdem sandstones of the Tripati group being made up of superficial deposits.

Lithology.

The fossiliferous band is variable in its constitution and thickness: it is, south of Dúdkúr, a hard brown and greyish sandy limestone of about 6 inches, resting on good sandstone which is rather calcareous. At the crossing of the road (mentioned above), it is a hard dark-grey sandy and earthy limestone of above 2 feet in thickness. Towards Gowripatnam the limestone band is not so definite; it shades down into a coarse brown calcareous sandstone, full of fossils, 2 feet in thickness, and this is the character of the outcrop still further on, past Gowripatnam. Near Devarapili, or about ½ a mile east of it, and to the south of the high road, there is a small section exposed in a *nala* at a little cliff over which the small stream falls and wanders through the fields below. There are, uppermost, about 5 feet of soft friable weathered fine-grained dull dirty greenish trap. This trap is lying and undulating slightly over limestone (crowded with *Turritellæ*) and yellowish and green friable sandstones; that is, the trap is sometimes covering up solid hard parts of the *Turritella* limestone, and close by, within a few inches, it is lying on the friable sandstone which is properly the lower band of the fossiliferous seam. In this short outcrop, the more calcareous band is very thin, or in massive blocks, or it has disappeared altogether, which feature may be due either to the seam of limestone having been originally deposited of a varying thickness, or, as I am more inclined to think, to its surface having been denuded prior to the flow of trap. The proper upper fossiliferous bed is not more than 4 or 5 inches to a foot in thickness; where the blocks or masses of bed are thickest (say 2 feet), there is an upper part about 6 inches thick of hard, compact, sandy limestone, with fragments of *Turritellæ* and other shells scattered through it; and below this is a more friable sandy clay limestone, crowded with fine and large specimens of these shells. The thick band of fossiliferous rock rests on yellowish and greenish fine soft sands, also containing a few fossils.

Turritella zone.

The distinctive and commonest fossil is a *Turritella*, the rock being often quite crowded with it. The other fossils are generally found in

the more friable seam below. The greatest show of fossils was, however, obtained from the Gowripatnam outcrop, and it was here that the fragments of *Nautilus* and the *chelæ* of the crab were found. The large blocks seen in the small temple and *chabutra* at Dúdkúr were doubtless obtained from the outcrops towards Gowripatnam, for I could see no thick enough beds for them anywhere near the village.

Fossils.

The dip of the beds is at 5°—10° south-east, or east-south-east; the more prevalent being about 10°.

There is no sign of any alteration of these beds by the superincumbent trap; they are good ordinary rough sandy limestones.

Apparently unaffected by superincumbent trap.

Regarding the age of these beds, they are certainly, for this region, older than the trap series, only it is not at all clear to what portion of this series these flows of the eastern coastal region belong; and they appear to have been denuded before the trap was poured out: indeed, as far as the generally massive condition of the trap goes, the surface over which they were poured may have been dry land; at any rate, it could hardly have been the bottom of the sea in which the shells now preserved in the rock lived. It will also be seen later on that the non-parallelism of these beds with the overlying trap and their intermediate fossiliferous band, and the overlap of these, are against the two being very closely connected groups of a series.

Relation to Deccan trap series.

The majority of the fossils are such as are usually considered as of tertiary age, particularly the *Gasteropoda*; but the prevalent *Turritella* appears to be very close to *T. dispassa*, Stol., a cretaceous species from the Ariyalúr beds of the Trichinopoly district.[1] The *Volutilithes* is very like *Voluta torulosa*, Desh., which is a Calcaire Grossier species.

Cretaceous affinities.

There is a strong resemblance, lithologically, between these beds and those of the Lameta group, as described by the late J. G. Medlicott for the typical locality on

Resemblance to Lametas.

[1] Cretaceous Fauna of Southern India, Vol. II.

the Narbada river,[1] and in the accounts given of other localities of this group by subsequent writers.[2] The position of these beds, underneath the trap, which is, I think, not perfectly conformable to them, but sufficiently separated from them by overlap and by denudation, is also in favour of these Dúdkúr beds being a marine representative of this group.

Views of W. T. Blanford.

Mr. W. T. Blanford has already discussed[3] the relations and age of these beds, regarding which he says, after a brief description of them and their fossils: "the most abundant of which is a *Turritella,* apparently identical with *T. dispassa* of the cretaceous Arialúr group. If not identical, the two species are very closely allied. A *Nautilus,* about fifteen *Gasteropoda,* and eleven *Lamellibranchiata* accompany the *Turritella;* but not a single species except *Turritella dispassa,* has been recognized as identical either with the cretaceous beds of Southern India or with the eocene fossils of the nummulitic group. The collections have not, however, been sufficiently compared to enable the species to be determined with any certainty. Only one single species, too, *Cardita variabilis,* has been recognized as occurring also in the overlying intertrappean bed. Although the whole facies is tertiary, there is a remarkable absence of characteristic genera, and the chief distinction from the cretaceous fauna of the upper beds in Southern India is simply the want of any marked cretaceous form. The fauna is distinctly marine.

"It is difficult to say whether this bed should be referred to the Lameta group or not. The mineral character is similar, but all known Lameta outcrops are so distant that the identification is somewhat doubtful. The distinctions between the fossils of the Bágh beds and those of the infratrappeans of Dúdkúr and Pungadi appear too great to be attributed solely to the existence of a land barrier between the two areas; it is difficult to suppose that the two formations can be of the same geological age, and the difficulty consequently arises that, if the

[1] Mem. Geol. Surv. of India, Vol. II, pp. 196-199.

[2] Mem. Geol. Surv. of India, Vols. VI, p. 216; IX, p. 315; XIII, p. 87, and Rec. Geol. Surv. of India, Vol. V, pp. 88, 115.

[3] Manual Geology of India, Part I, p. 316.

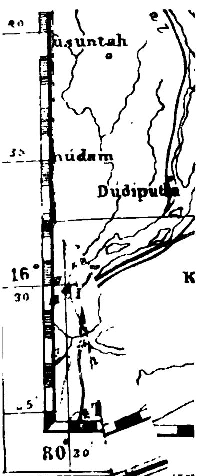
Lameta beds represent the Bágh group, they are probably more ancient than the Pungadi infratrappeans. Still the balance of evidence is rather in favour of referring the latter to cretaceous times than to tertiary. They may be of intermediate age.

Traps and intertrappeans.—The Dúdkúr beds are overlaid by coarse compact blackish-green basalts, which attain a thickness of nearly 200 feet and extend far to the east and west, lapping on to the gneiss in the one case and the Tripati sandstones in the other. About half way up this thickness of traps, there is a thin band of fossiliferous limestones; but this does not always lie in the middle of them, or parallel to the strike of the Dúdkúr beds which have the greatest thickness of trap on them at their eastern end, while there is again another thickening out of the traps at the western extremity of the field to the south-south-west of Devarapili. At Dúdkúr there are only some 27 feet of trap between the *Turritella* limestone and the intertrappean band; while at the road crossing further east there must be a thickness of 40 feet at least below the seam of limestone as it passes round the spurs in the direction of Pungadi.

Overlap the infratrappeans.

In the valley south-south-west of Gowripatnam, the band of intertrappean limestone is about 4 feet thick; and to the east of this, it thins down to 2 feet in the direction of Pungadi. Towards Dúdkúr it thickens out to 8 or 10 feet. The seam is generally of two or three or more beds the rock being very often a compact crystalline slightly magnesian limestone of white, pink and grey or greyish-green colours, but oftener grey; at other times it is very coarsely crystallized and fibrous in bands and seams of alternating crystallized and fibrous structure with pearly lustre, or often, rudely nodular and concretionary with a radiating fibrous structure. Then again the rock is less crystallized, or dull compact, or soft and friable. All these different structures and conditions are of course on the weathered outcrop, or in the quarries where it is presumed that the more generally crystalline character of the rocks becomes changed by exposure; and they are so irregularly distributed through the thickness that it is quite

Thickness and lithology.



On Stone by S.

impossible to say whether any portion has been more particularly affected by any possible alteration consequent on the eruption of the traps. The impression produced is, that the limestone band has certainly been altered in some way, and naturally by the trap which was found over it. The fossils are only seen in the less crystalline or clayey seams,[1] which are those that are mainly quarried and picked out, at various points along the hill side, as when the high-road crosses the outcrop in descending from Pungadi towards Gowripatnam and in the bay south of that village. Here, the uppermost layer is an *Ostrea* (*O. pangadiensis*) bed, which in some places is chalky-white and crumbly, with nodules of hard compact limestone. The *Ostreæ* are also found scattered about on the ground, having weathered out of the rock. The other fossils are seen here and there throughout the middle of the seam in hard half-weathered grey limestone, the bivalves being particularly crowded together. Much of the seam in the valley south of Gowripatnam is of thick beds of coarsely and finely sub-crystalline yellowish rock with nests and strings of more lustrous brown and grey saccharine limestone and calc-spar. The upper bed or layer is at times a pale-brown or yellowish (weathering of a darker colour) sub-crystalline limestone, the *Ostreæ* standing out on the weathered surface but scarcely recognizable in the interior and unweathered portion of the rock. To the west of Dúdkúr, the band of limestone again becomes very thin and is eventually scarcely recognizable to the south of Devarapili.

The dip of this seam to the south or south-east is very slight, in fact, it is often almost horizontal.

Fossils.

I obtained the following fossils from the Pungadi outcrop :—

? *Nassa.*
Pseudoliva elegans, Hislop.
Natica stoddardi, Hislop.
? „ 2 sp.
Cerithium subcylindraceum, Hislop.

[1] The massive beds are less easily quarried, and, as the principal use for the stone is for lime-making, the contractors prefer to collect it from weathered outcrops.

Cerithium leithii, Hislop.
" *stoddardi*, Hislop.
Vicarya fusiformis, Hislop.
Turritella prælonga, Hislop.
Physa Prinsepii, Hislop.
Ostrea pungadiensis, Hislop.
Perna meleagrinoides, Hislop.
Septifer, sp.
Corbicula ingens, Hislop.
" sp.
Corbis elliptica, Hislop.
Cardita variabilis, Hislop.
Cytherea, ? sp.

These are all perfect specimens, and there is a fair number of each of them; *Ostrea, Lima, Modiola*, and *Corbicula* having only been previously known from these beds. These specimens were principally got out of the quarried lumps of rock which had been carted from the line of quarries at the head of the shallow valley south of Gowripatnam and laid down near the travellers' bungalow at Pungadi: the rock had become somewhat weathered by being there left lying out in heaps, and thus the shells were exposed and easier knocked out. There is no doubt, however, that they are all from these intertrappean beds; the one thing not known is their relative position in these beds, though some clue is given to this in the account I have given of the few shells obtained *in situ*.

Kátéru outcrop.

On the Rájahmundry side, or left bank of the Godávari, and about 2 miles along the road to Korekonda, there is a low headland of basalt overlooking the alluvial flat to the north, at the base of which a long line of quarries has been sunk in beds of yellow and buff limestone. These quarries are in the form of a long trench which has been unfortunately filled up in great part by the discarded debris of the calcareous rocks, so that the bottom of the outcrop is always covered up, and I do not think a clear exposure of the junction between the lowest beds and the underlying trap has ever been noted. However, in a small stream bed (*nala*) at the north-east end of the quarries, the underlying basalt is exposed at only a

few feet lower down than the limestones. On the other hand, the contact of the upper beds and the overlying trap is often clearly exposed.

Fossils are not very easily got out from the exposed surfaces, nor are many to be seen, except when the quarries are re-opened at the end of the rains and when the outcrop and the debris thrown out during the previous working season have had some time to weather.

Between this outcrop and the village of Kátéru (half a mile to the west), a further trench has been opened up in limestones which appear to belong to another and lower band; but this is not sufficiently clear, as the dip is very low in both bands, while the second of these is rather to the south-west of the first, so that by the mere flatness of lie it is possible that the latter may be a continuation of the former. I think myself that there are two separate bands, because the rocks differ in some respects, and no fossils are known from the western outcrop. The natives (and the views of quarrymen who have worked from their childhood at these beds are not to be lightly thrown aside) say that the two outcrops belong to one and the same band. One thing is clear,—the western outcrop is also underlaid by trap.

Two outcrops, doubtfully of the same band.

The limestones of the band nearer Kátéru are on the whole much more crystalline than the rocks in the fossiliferous band.

The trap.

The trap, both above and below the limestone bands, is a dark-green or greyish compact basalt, very much weathered all over the outcrops and well in below the surface. It has a strong tendency to separate in rounded masses and blocks, with rudely concentric laminæ surrounding cores of the solid unweathered rock; and so much is this the case that it has been found very difficult to obtain blocks large enough for the irrigation and canal works in the district. There is an indistinct sort of lamination parallel with the strike of the intertrappean beds when vertical surfaces are exposed, as near the quarries; but there is no thick enough exposure anywhere on the slopes, either here or in the Pungadi field, to show any such bedded lie as is developed among the traps of the Deccan proper.

There is occasionally a good deal of silica segregated through both upper and lower bands, in the form of calcedony agate common opal and rock crystal in amygdala and geodes, and large masses of calc-spar are common; but all these are more frequent in the Pungadi field, where the exposures are vastly larger.

In the face of the Kátéru quarries, the trap, when least weathered, is a compact dark-brownish-green earthy rock separating in rude sub-angular masses with large sub-conchoidal faces. The bottom edge of the upper trap is weathered for a few inches of a yellow colour; it is also amygdaloidal with small kernels of dark olive-green clayey matter, the vesicularity being strong for 3 or 4 inches and then rapidly disappearing.

The contact of the limestones with the underlying trap is, as already observed, not exposed.

There are about 100 feet of the upper traps, which are again overlaid by the Rájahmundry sandstones; the thickness of the subjacent band is unknown, but the stream channel at the north-east end of the quarries shows from 40 to 50 feet of them.

The intertrappean band.

The intermediate band of limestones is, when best seen, from 12 to 14 feet in thickness; but it thins out to the north-east and is not found at what ought to be its point of outcrop on the Korekonda road. It consists of beds of varying thickness, none of which are constant for any length; but the following is the arrangement of beds generally met with, in descending order:—

1. Dark chocolate-brown and greenish clayey mud.—8 or 9 inches.
2. Dirty greenish fossiliferous calcareous mud, hardening somewhat on exposure, —A few inches, to a foot or more in thickness.
3. Earthy, clayey, brownish and pale-coloured limestone; with occasional fossils. —1 to 2 feet.
4. Compact waxy pinkish limestone.—1 feet.
5. Yellow ferruginous clayey limestone.—2 to 3 feet.
6. Compact waxy limestone, changing downwards into crystalline and fibrous pearly-grey, brown, and reddish dolomite.—6 to 8 feet.

All these, except the fossiliferous mud, may be found more or less

crystalline and arranged in seams and large nodular masses with vertical or radiating structure, and they go wavering about and tailing into one another, no beds but (5) and (6) being very constant.

More or less crystalline.

No. 1 seam has always an even upper surface, but it is not always present, the trap being sometimes in immediate contact with the fossiliferous seam No. 2;—indeed, it sometimes happens that this latter bed thins out, and then No. 3 is overlaid by the chocolate clay No. 1.

Thinning out of beds, and denudation.

It is to me a matter of considerable doubt as to whether this chocolate clay is not an accompaniment of the trappean outburst, rather than a final deposit of the intertrappean band. It might have been a very fine dust, and it is curious how its upper surface should be so worn.

The upper surface of the layer No. 2, or the fossiliferous mud, is uneven and shows gaps here and there, as though it had been subjected to denuding forces prior to the overflow of the trap, or, at any rate, to the deposition of the chocolate clay.

There are cases in which the greenish calcareous fossiliferous sand is absent altogether, when at times the rest of the band is more or less crystallized right through.

The dirty-green calcareous mud is full of fossils, particularly *Cerithium subcylindraceum*, *Vicarya fusiformis*, *Turritella prælonga*, and a few small bivalves. Others, such as *Cerithium stoddardi*, *C. leithii*, *Nassa*, *Corbicula*, and *Cytherea*, &c., are found in the more massive buff limestone below the mud seam. One specimen of *Physa* was obtained from the fossiliferous mud.

Fossiliferous seam.

The whole length of outcrop at Kátéru is not more than about a quarter of a mile.

There is no doubt that here in the Kátéru area there is apparent alteration of the intertrappean beds from below upwards, that is, they are generally more largely crystalline and fibrous towards the bottom, and as is the case with the infratrappean beds, the strata nearest to the

Apparent alteration of beds from below upwards.

superincumbent trap do not appear to be altered at all; and the first idea that strikes one is that for which Hislop contends, namely, that the alteration must have been produced by the underlying trap, or (to put it more correctly) this is the view Hislop takes of the situation near Nágpúr, and he indirectly extends it to the Rájahmundry area, though it must be remembered that he never saw the latter.

Case against alteration.

A very important point here is, that if the traps between the infratrappean beds and the intertrappean zone were intruded, they might be expected to have altered the contact beds equally above and below; but there is no more sign of their having altered the subjacent beds than there is of the uppermost trap having altered the fossiliferous layers on which it was poured.

Influence of weathering.

Again, it seems to me that any direct alteration by the traps may have been completely obliterated by weathering, and this would account for the unaltered look of the infratrappeans, and of the upper portion of the intertrappean limestones.

Explanation.

The real facts of the case appear to me to be, that the condition of alteration from below upwards is only apparent, and due nearly altogether to the varied constitution of the beds, while the metamorphic action of the superincumbent traps was not very strong. The general constitution of the beds in the fossiliferous outcrop at Kátéru is, that the lower beds are more purely calcareous, while the upper beds are less and less pure, or are more and more clayey, until in the topmost beds they are calcareous muds. In the Pungadi outcrop the clayey bands are rarer, and there is, as far as I could see, no representative of the muddier beds; and as a consequence, the alteration or the degree of crystallization is more persistent throughout the whole thickness, there being still, however, a more purely calcareous constitution in the lower beds. At the same time, throughout the two outcrops, there is a good deal of tailing in of the limestone beds among the more clayey ones, and thus, at places, we find the crystalline character waving irregularly up and down the series.

The late Mr. J. G. Medlicott, long ago,[1] discussed the view of Hislop as to the probability of the intertrappean beds of the Central Provinces having been invaded and altered by a subjacent sheet of trap; and in the area examined by him he shows very good evidence against this view, principally that "in every case within our experience, the sedimentary beds have been deposited tranquilly on the *previously indurated and moreover previously denudated surface* of the trap rock: and in several cases a large portion of the material constituting these sedimentary beds is derived from the debris of the trap flows themselves." Unfortunately, the sections at Pungadi or Kátéru do not give such clear views of the condition of the subjacent trap; nor did I see a case of any inclusion of material derived from it. On the other hand, though Medlicott is quite as decided in his remarks as to the altered condition of the sedimentary beds between the two traps being from above downwards, still he gives a section illustrating the exceptional developments of the intertrappean rocks, that is, developments in which the alteration is variable, or is distributed through the beds in the opposite direction to that usually obtaining, or again, when there is no apparent alteration at all; which section, on comparison with the details above given, will show what a strong resemblance there is between the conditions of the rocks in this exceptional case and those more general ones in the Kátéru and Pungadi outcrops.

Apparent alteration of beds in Central India.

Concerning this section[2], he says:—"It is exposed in one of the glens of the Gorchutta valley, a few miles from the village of Singwarra.

"In descending order—

"30 to 40 feet of sub-columnar trap, showing well a concentric structure. * *

3 feet to 6 inches of dove-coloured grey earthy limestone, containing many shells. This bed, which varies (as stated) considerably in thickness, does not seem to have been even slightly influenced by the superincumbent basalt. It rests on—

6 to 7 feet of a mass which is made up of irregular lenticular patches dying out and replacing each other, and which differ from each other as follows:—

a).—A grey limestone, somewhat like the bed above, but is more earthy,

[1] 1860, Mem. Geol. Surv. of India, Vol. II, p. 208.

[2] Mem. Geol. Surv. of India, Vol. II, pp. 203-204.

and contains fewer shells. Though less calcareous on the whole, it is traversed by many veins of pure carbonate of lime, which do not occur in the upper bed.

(*b*).—A fine-grained green loam with an incipient concretionary structure, containing a few threads of carbonate of lime, no shells.

(*c*).—The last-named variety passes into this one; the veins of lime become larger, and highly crystalline, until the mass is a crystalline limestone, with a few flakes and strings of the green earth, and these at last disappear. The limestone is a faint yellow or drab colour, and very coarsely crystalline. The facets of the crystals have the pearly lustre of dolomite."

" Beneath this comes trap, * * * "

Such exceptional cases did not affect the general and more natural condition of affairs in Central India; but here on the eastern coast, it has seemed necessary for me to state the apparent condition of the intertrappean beds, which I feel sure Hislop, had he seen it, would have seized on as helping to favour the far-fetched, though fascinating, explanation which one is sometimes apt to take when considering the possible action of intrusive trap sheets. I have gone over this Lower Godávari outcrop of traps over and over again with Hislop's theory before me; but the intrusion of 40 or 50 feet (at the lowest calculation) of traps for a length of what must have been at least 14 or 15 miles between the infratrappeans and an intertrappean band of 12 or 14 feet thick was so inconceivable a phenomenon to me that I was ultimately driven to hold by the simpler theory of a pouring out of the upper trap over a estuarine deposit which had been simply laid down on a previous flow.

Relation of this outburst to that of the Deccan.

This very small patch of traps and associated rocks is so isolated here on the eastern coast from the well-known immensely greater development of traps in the Deccan that it is difficult to conceive how they can be connected either by previous continuity or by contemporaneity; for though their distance (200 miles) from the traps is small as compared with the length or breadth of the Deccan area, still they are entirely isolated without any connecting outlier between them and it. There is,

however, the connection by their associated deposits and their fossils: and it seems almost certain from these, that they and the lowest division of the traps of the Deccan are contemporaneous to some extent.

Age of intertrappeans.

Mr. Blanford, in the Manual of the Geology of India and in other works, has treated very largely of the Deccan traps, and ranges the lower member of them as preferably of upper cretaceous age; or rather, that the volcanic outbursts began while the upper cretaceous rocks were being deposited on the south-eastern coast of India.

The occurrence of the infratrappean beds of Dúdkúr, with fossils having what appears to be a cretaceous facies, and on which I think the traps are slightly unconformable, would imply a somewhat later age than this; but it is possible that when the collection of these fossils is thoroughly and competently examined, the correlation may be drawn closer.

Hislop's view.

The intertrappean beds are clearly of the trappean period, and they are in some respects rangeable with Hislop's intertrappeans of Central India; but the latter are essentially of lacustrine or fresh water origin, while the Pungadi and Kátéru fauna is estuarine. However, there are three shells common to the two, namely, *Paludina normalis, Physa prinsepi* and *Lymnea subulata*, and, as it appeared when Hislop wrote, there seemed very good reason for his conclusion that the rocks of the one locality were a fair estuarine representative of the lacustrine rocks of the other, and that they are of lower eocene age.

Blanford's view.

I am unable myself to enlarge on or narrow Hislop's generalization further than to instance the fact that the traps do not appear to be disassociated from the infra-trappean beds in this locality to such an extent of unconformity as the supposedly upper eocene age of the intertrappean beds would require. W. T. Blanford has, however, entered on this question with reference to the character of the mollusca of these latter beds in the following extracts from the Manual of the Geology of India [1]:—"The mollusca, however,

[1] Part 1, p. 319.

cannot be considered as very characteristic of age. They were compared by Mr. Hislop with the nummulitic fauna of Western India; but, as he points out, no forms appear to be identical, and although *Natica dolium*, *Turritella affinis*, and an unnamed *Cerithium* found in the tertiaries of Sind and Cutch, resemble *N. stoddardi*, *T. prælonga*, and *C. stoddardi*, the intertrappean forms are more closely allied to the cretaceous *N. (Mammilla) carnatica*, *T. elicita*, and *Cerithium vagans* than to the eocene species mentioned [1]; and other forms might easily be shown to be affined to those occurring in the cretaceous rocks of Southern India. In the case of *Turritella prælonga* and *T. elicita*, the affinity is very great. The shell called *Vicarya fusiformis* appears not to be really congeneric with *V. verneuilli*, the type of the genus [2]; and the latter has now been found to be miocene, not eocene. On the whole, it may be safely asserted that no tertiary alliances of any value have been detected amongst the intertrappean Rájahmundry fossils, and that their relations are rather with the upper cretaceous rocks of Southern India, although the connection is not strong."

CHAPTER V.—CUDDALORE SANDSTONES.

Rájahmundry Beds.—Both at Pungadi and close to Rájahmundry, the uppermost trap is overlaid by a series of reddish sandstones and conglomerates, which in other parts of the field extend far over the gneissic, jurassic, and Rájmahál rocks. As far as is known, they are entirely unfossiliferous, and thus their age is only to be made out from the fact that they evidently are strongly unconformable by overlap on the trappean series.

They bear a wonderful resemblance to the *Cuddalore sandstones* of the Carnatic, and in fact must be considered as representatives of these.

[1] "When Mr. Hislop wrote, the South Indian cretaceous fossils had not been described."

[2] "This was pointed out by Mr. H. M. Jenkins, Q. J. G. S., 1864, p. 58. He also (p. 65) suggested that the Sind beds containing *Vicarya* were newer than eocene,—a view since confirmed."

They form four patches of slightly-elevated and somewhat hilly ground on the edge of the deltaic alluviums, which may be considered under the names of the Rájahmundry-Sámalkot, the Pungadi, the Pentlum (further to the south-west), and the Dúdúgut (south of Ellore) patches being separated from one another by the Godávari, Yera-kalwa, and Tammilér rivers.

Extent and mode of occurrence.

Each of these patches rises gently to the north in low plateau form, seldom attaining an elevation of more than 250 feet above the sea. In the larger area, or that of Rájahmundry-Sámalkot, there are a few small flat-topped hills in the interior, as to the north-west of the latter town, along the northern edge, and again at the western end where the sandstones face the Godávari in some low scarped hills and plateaus which run down to the river bank in low spurs at Rájahmundry and Dowlaishweram. The hills near the latter place have been long known for their stone, which was quarried and run down into the river for the great *anicut* or dam which here stretches from bank to bank (with an intermediate '*lanka*' or island) for a length of more than 2 miles across the river.

The general succession of beds in the main areas is, lowest, exceedingly coarse and harsh red and pinkish hard conglomerates and sandstones, felspathic, such as may be seen in the river face of the town of Rájahmundry, and away north-east towards Kátéru or along the road to Vizagapatam. In this latter direction, the ground is covered to such an extent with the coarse gravel and debris of these beds, that clearings had to be made for the few good riding grounds in the neighbourhood. Several wells have been sunk through these sandstones, gravels, and heavy conglomerates, as at the Central Jail, on the northern edge of outcrop, the deepest of which is 91 feet, but without piercing the series; so that there are at least 100 feet of these coarse beds over the traps of Kátéru.

Succession and lithology.

Over these coarse beds come yellow-brown and reddish friable clayey sands with, uppermost, white (purple mottled) and red soapy clays, rather hard and much given to breaking up in irregular fragments.

With these upper clays are seams of brown and pink ferruginous sandstones. There may be 150 feet of these less compact sands and clays, as made out from the plateau hill south-east of Rájahmundry.

These are succeeded by heavy and coarse dark-brown, nearly black, thick-bedded sandstones, occasionally quite vitreous and not unlike quartzites. The coarser beds are made up of fine angular grains of clear glassy quartz, dirty quartz, and jasper clay-ironstone, cemented by dark-brown peroxide of iron. With these are also seams of hard scabrous (lateritoid weathering) ferruginous sandy indurated clays. It is in this band that the Dowlaishweram quarries have been worked, and it forms the cappings of some of the small plateau hills east and south-east of Rájahmundry. The long south-east slopes of the quarry hill north-east of Dowlaishweram are made up of brown ferruginous sandy indurated clay beds. The thickness of the band is, at the greatest, about 30 or 40 feet.

Over this, again, was a further good thickness of white and purple mottled and red soapy clays, with brown and pink sand, which only remains now as outlying hills and plateaus east of Dowlaishweram, as at Rázálú hill, &c. On the top of this hill there are soft friable pale-brown coarse ferruginous sandstones. The long southerly sloping plateaus, with headlands to the north, in the direction of Kuddum, have, in addition to this capping of sandstones, another of lateritic sandstone or laterite, which may, however, be of somewhat later age.

We have, thus for the Rájahmundry sandstones at their thickest, the following series in descending order :—

4. Upper white and red clays and sands, with capping of soft reddish and brown sandstones, about . . .	100 feet.
3. Thick-bedded brown, occasionally quartzitic, ferruginous sandstones of Dowlaishweram hills, about . .	30 „
2. Intermediate soft soapy clays and thin-bedded friable sandstones	150 „
1. Heavy conglomerates and reddish felspathic sandstones of Rájahmundry town	100 „
	300 or 400 feet.

Very much the same series occurs at the Sámalkot end of this area, where the beds run up into rather elevated ground towards and beyond Peddápúram. This high ground is, however, I think of the Dowlaishweram beds, and is largely quarried. The fort beyond Peddápúram is built on the lower beds of the band, or on the upper part of the intermediate band of white and red clays; and the colour of these is so bright and rich, that the fort, ridges, and hills around, which are also much surrounded by trees, often present a most glowing picture in the morning or evening light.

The Pungadi plateau is made up of the lower conglomerates and sands only, and here the bottom beds are well exposed along the northern boundary, where they form at times a low scarp of a few feet over the upper trap slopes; and also a couple of small outliers on the trap headlands to the west-north-west of Pungadi. The lowest beds are coarse hard sandstones and heavy conglomerates of fragments and pebbles of clear quartz and quartzite, having sometimes a matrix of hard ferruginous clay though the usual cement is simply brown peroxide of iron. The higher beds, as in the rising ground to the south-west of Pungadi, are coarse yellow and buff felspathic sandstones, not at all unlike some Kámthi beds, or the Trípati beds above the Rágavapúram shales.

The further Pentlum patch is also of the lowest beds; but this is a very low-lying area, hardly to be recognized, except here and there, as much higher than the alluvium along its northern edge. Some of the beds in this patch are highly ferruginous, and these are worked for iron, which is rudely smelted at two or three villages, principally near Marillamúdi and Dóbcherla.

The Dúdúgut area is again a rather elevated plateau-like range, the back and scarps of which consist of dark-brown and red, sometimes nearly black, hard, and often vitreous, sandstones and heavy conglomerates, which are here capping sandstones of the Gollapili beds of the Upper Gondwánas. They are more like bottom beds of this latter group, as it is developed in the Kamerapúkota country, or as often like the

Tripati sandstones. On the whole, however, they answer best, by their constitution and position, to the lower beds of the present group.

The old diamond mines of Muléli on the south-west edge of this patch were partly worked in these sandstones.

The lie of the Rájahmundry beds is at a very low angle to the south-south-east, at about 5° or so; occasionally they are nearly horizontal. At Dowlaishweram, there is a good deal of undulation and various dipping on the quarry hill, accompanied by strong alteration of the beds almost to the condition of quartzites, evidently the result in great part of local squeezing and faulting. The dip is on the whole, that is, over the whole field, rather more to the southward of east than is the case with the beds in the trappean series.

The unconformability and overlap of this set of sandstones on the Deccan traps are after all much more decided than those existing between the ages of infra and intertrappean deposits, showing that it must be considered as belonging to a series of much later age, or that it is undoubtedly of the tertiary system, and possibly of middle eocene age. We are thus able to give the Cuddalore sandstones, which were only known in their own field to be post-cretaceous, a rather more definite position, though we must still wait for that further evidence which shall probably be deduced from the occurrence of tertiary fossiliferous strata known to be associated with the laterite, or, possibly, sandstones of this present series in the neighbourhood of Quilon on the western coast.[1]

CHAPTER VI.—ECONOMIC GEOLOGY.

Building stones, &c.—Beyond the occurrence of very good building stones, such as those obtained from the different sandstone groups and the trappean series, and the limestones associated with these, which have been very largely used for mortar, there is little of economic interest in this part of the Godávari district, as far as the development of other

[1] *See* Manual of the Geology of India, Part I, pp. 337-338.

mineral resources is concerned. At the same time, the sandstones of Peddavegi, Tundkalpúdi, and Jánampet (north-north-west of Ellore) are worthy of special notice. That of the first locality is a tolerably compact even-grained rock, in good thick beds, easily worked, and, like most red sandstones in India, given to hardening considerably on exposure, though in the latter process of change its usual brilliant red colour is given to fade or turn brown, and thus the stone is not so well adapted for external ornamentation. The finer and more brilliantly vermilion red variety is one of the handsomest stones I have seen in India, and it would be well worth carrying great distances, as by the canal which is close by, for interiors. The more useful stone is, however, the buff granular felspathic rock of the Tundkalpúdi scarp, which appears to be of perfect durability: it certainly exceeds in this respect any gneiss of this part of the district. The old pillars of many small temples in the neighbourhood have become, in a sort of a way, porcelanized on their surfaces, the matrix or hard clayey medium enclosing the quartz granules having become glazed over, while the latter stand out a little over the surface giving a rough but still rounded somewhat saccaharoid surface to the stone. The old unused blocks lying about near the quarries at Jánampet are weathered and hardened in the same way, and they are said to have lain there from time immemorial, the pagoda for which they were intended never having been completed.

Such are the specialities among the sandstones; but good stone is to be obtained in many other places all over the sandstone area. Thus, near Peddapúram in the Sámalkot area, there is very good building material in what appears to be the same band of beds in the Rájahmundry sandstones which has been nearly worked out at Dowlaishweram.

Diamond workings.—A far greater interest attaches itself, however, to the sandstones of one particular part of the district, namely, those near Muléli (to the west of Ellore), which are reported to have yielded diamonds. There is no doubt that these sandstones of the low plateau above the village have been broken up and searched for diamonds, as have also the recent deposits in the valley below; but they are not

worked now, nor are they thought of in this way; just as very many of the diamond-mining localities in the Cuddapah, Kurnool, and Kistna districts are now quite deserted. Still, in all these other places of mining or washing with which I am acquainted, the works have been either on known diamond-bearing rocks or in alluvial deposits presumably derived from and in the neighbourhood of them.

At Muléli, the old workings are either in very pebbly sandstones of the Dúdúgut range, which are not known as diamond-bearing in any other part of India, or are in superficial deposits collected below the range and presumably consisting for the most part of the debris of these sandstones. There is of course no reason why diamonds should not occur in these beds just as well as they occur in sandstones (quartzites) of the vastly more ancient Banaganpili group of the KURNOOL FORMATION[1]: indeed these very sandstones above Muléli are most likely in part made up of the debris of these Kurnool rocks; but the fitfulness of composition of such reformed and derived rocks, and their difficulty of being worked as compared with alluvial patches, only make the chances of successful working poorer. At any rate, whatever may have been the productiveness of the Muléli mines in old days, they are now in a state of desertion, and have been so for at least half a century.

I myself only saw, by the numerous old pits dug over the flat-bedded sandstones to the north of the village, both in the Rájahmundry sandstones of the Dúdúgut range and in the Góllapili beds underneath, and by the ruins of old washing troughs and sorting floors, that diamonds had been sought for and probably found. But I believe also that many of the pits were, on the other hand, dug for iron ore, such search being still in progress at the time of my visit.

Dr. Heyne gives, in his third tract, an account of the diamond mines at Muléli (Mallavilly), which, however, enters into little detail, and is really subordinate to a description of those of Cuddapah and Kurnool. According to him, the Muléli workings seem to have been mainly

[1] See Mem. Geol. Surv. of India, Vol. V, pt. 1.
[2] *Op. cit.*, p. 92.

alluvial, and these were carried on in the plain around the village, the ore or gravelly bed being some 14 feet beneath the surface, in the kunkury calcareous travertine) clays so common in the older alluvial deposits.

Voysey, Benza, and Newbold also refer to these mines in their papers already quoted; but only to the general effect that the diamonds appear to have been obtained from the sandstones of the plateau, or the alluvial grounds of the valley, but that no productive work appeared to be going on in their time.

My colleague, W. T. Blanford, who passed over the ground before I did, refers to the region thus:—"The low rises south of Gollapili are covered with the remains of old diggings, said to have been diamond mines. I could not learn how long a time had elapsed since the works had been abandoned: an old man, at least 60 years of age, told me there had been no mining within his recollection, and the pits have all fallen in, the whole country being covered over with thick bush jungle. The diggings appear not to have been in the sandstone itself, but in the very gravelly laterite which rests upon the sandstone, but the surface is so much broken and altered by the pits that it is difficult to say. The workings evidently cover a very considerable area, and are part of the old diamond mines of Golconda,[1] the ancient name of the hill range north of the Godávari and the adjoining country."[2]

Iron-smelting.—The iron industry of this part of the country might be improved to a great extent, for there are large stores of ore distributed through the sandstones of Gollapili, Tripati, and Rájahmundry, but as yet only small workings are carried on in the usual desultory manner in a few localities. The general source of the ore is naturally from that group of sandstones which is the most extensively exposed, namely, the Rájahmundry group; in the other groups there are only edge outcrops for the most part, or much smaller surfaces; for it is to be remembered that the natives only work at the more easily-obtained

[1] "See Voysey, Journ. As. Soc., Bengal, 1833, p. 403; Newbold, Journ. As. Soc., Bengal, VII, p. 232."

[2] Rec. Geol. Surv., India, Vol. V, pt. 1, p. 27.

ores, or such as are exposed to weathering or detrital influences, and these are the red and brown peroxides in manageable fragments, with often small cores of the grey or micaceous iron ore.

The places where I have noticed iron furnaces are in the sandstone region between the Yera-Kalwa and Tammilér rivers, or in the Pentlam patch of Rájahmundry and other sandstones near Nullacherla, and further north at Komera in the Tripati scarps. There are also others in the Núzvíd area, at Rámakapéta and Somavaram; and Heyne describes another locality at Latchmipuram in the Pungadi patch of sandstones.

The Pentlam area.—Some of the beds in this field are, as already noticed, highly ferruginous and much banded with clay-ironstone concretions, &c., and the debris of these, as well as the beds themselves, are worked and rudely smelted at Marillamúdi, Jaganátgúdem, and Dóbcherla. At the first place the ore used is a dark-brown and purple clay-ironstone, which occurs in small lumps in a lateritoid gravel on the south side of the village at a depth of about 15 feet, whence they are dug up by the people from shafts, at the bottom of which they grub about for a few feet. The furnaces of this part of the country are somewhat different from those I have seen in Southern India, in so far as they are not complete truncate cones, but only half completed, so that one side of the interior chamber is left open when the furnace is not in use. At every smelting, this open side of the chamber is closed up by a thin slightly-curved wall of clay plates or slabs luted together with wet clay; this side of the furnace being flat, while all round the bed of the chamber there is a backing of 2 to 3 feet. A conical chimney of about a foot in length is placed over the top of the chamber, and on this again is placed a broken half of a country chatty or earthenware pot, through which a hole has been broken, so as to act partly as a funnel for the readier throwing in of the ore and fuel. At one side of the furnace there is a hollow having a small communication with the floor of the furnace, and through this the slag or cinder is drawn off from time to time. After the smelting the wall is broken

down and the bloom removed. At this place there were two furnaces and forges at work, and only one at Jaganátgúdem.

At Gopallapúram, a couple of miles to the south, the ore is obtained from purple and brown ferruginous sandstones occurring in 6-inch beds.

The Koméra ore is a red and brown, rather yellowish, clay-ironstone obtained from the sandstone beds towards Tripati. Here I had an opportunity of seeing one of the blooms drawn. The clay wall in the front part of the chamber was broken down and carried off in large pieces (to be used again), and the burning charcoal raked out, when a man pounded the pasty—but still, on the surface, in a state of slow ebullition—mass of metal at the bottom of the furnace for a few seconds with a heavy wooden mallet. Then a huge pair of iron tongs was brought forward and rammed, or rather chopped down, here and there on the mass of metal, during which time it hardened sufficiently to allow of one arm of the tongs being lowered down the side of the pit when the bloom was clasped, hauled out, and carried off to a small pit or hollow in the ground lined with charcoal dust. The partially flaming mass was now heavily beaten over its upper surface (the old under-surface on the furnace floor) for some time with wooden mallets, after which it was left to cool, though a lot of old slag and cinder was piled up around it, but not over it, while a red-coloured dross from the floor of the furnace was ladled over the upper surface. After about 10 minutes the bloom was then partially split up by wedge hammers, which left three deep clefts in one side. The blooms are larger than those of Southern India, and are said to be about 2 maunds (Madras), or 80 lbs., in weight, and of the value of 4 rupees when handed over to the contractors. Two furnaces were at work here, and the measurements of each of these were:—height, without chimney, 4 feet; breadth across the front, 5 to 4 feet, tapering; width from front to back, 4 to 3 feet, tapering, the front being nearly vertical. The chamber is about 1½ feet in diameter widening to the floor which is about 2 feet; and the whole is surmounted by a tapering chimney with funnel top of about 2 feet high.

In the Núzvíd region, there were only three furnaces at work at Rámakapéta, and two at Somavaram; the ore being obtained from the debris of the bottom beds of the Gollapili sandstones.

The old iron working at Lutchmipúram, where I was told smelting is still pursued in a small way, is so well described by Heyne in his tract[1] on the subject, that I take the liberty of reproducing the greater part of it here, as it will add considerably to the few details I have been able to collect during my hurried visits to these iron villages, most of which I only came on by chance and while hastening to more important work.

Dr. Heyne's account.

"About the end of the month of June 1794, when the thermometer stood at 115,° I set out from Vuppáda, for Letchemporam, a small village in the Polaveram district. This village lies about 14 miles south-west from Rájahmundry. I found the people in this village extremely willing to show and explain to me everything concerning their iron works.

"The iron-smelters themselves are a poor set of people, and obliged to plough the land for their subsistence during the wet season, and work as smelters only during the hottest part of the year. The finest and mildest season they employ in cutting wood in the hills, in burning charcoal, and, after these occupations are over, in recovering their health at home; for, besides their repeated experience that every one contracts the fever during his stay among the jungle, we have only to observe their sickly look and their whole appearance, to be convinced that their accounts are correct. To this circumstance, together with the necessity they are under of cultivating the ground for a part of the year, we may ascribe the unproductiveness of their labour as manufacturers of iron. Yet the iron which they produce is considered as the finest in every respect for tools, razors, etc. Hence the demand for it is great, and the number of workmen miserably small, for the miners, smelters, wood-cutters, and labourers, all united together, do not exceed eight or nine men.

"Stones containing iron ore in considerable quantity are found every

[1] *Op. cit.*, p. 218.

where near the village, from six to eight fathoms under ground, imbedded in a lithomarge, the discovery of which is a sure sign of being near a bed of iron-stone.

"These iron-stones lie in beds of a small extent, of irregular thickness, and various in their breadth from side to side, though this is never very great.

"They at first mine downwards in a perpendicular direction, till they are obliged by the different directions of the beds to alter their course accordingly. The breadth of their perpendicular shaft amounts to about 2½ cubits, and small steps are cut out in the sides for the convenience of descending. When they have exhausted a bed of iron-stone, they abandon their mine without any further trial, and dig another in a different direction. This negligent mode of proceeding puts them to many inconveniences, and produces much unnecessary trouble, by obliging them to dig holes almost every six yards, which they fill up again when the iron-stone is exhausted.

"The ground in this place, and the ore itself, being of a very soft nature, no other instruments are required for working their mines than a pointed pickaxe. The ore and extraneous stones are drawn up in baskets; the latter (consisting chiefly of clay) is separated, and the former broken by mallets to the size of a hazelnut.

"This ore has much the appearance of a yellow and brown ochery clay. It appears also to contain a mixture, or rather coating, of calcareous earth. When reduced to powder, it acquires a red colour, and exhibits many sparkling particles.

"The miners prepare the charcoal which they require for smelting this ore, by burning the wood of the *Sandra chettu* (Mimosa sandra), which furnishes a solid, good charcoal; but as it is rather scarce in the vicinity of this village, and as a conveyance of 24 or 30 miles, the nearest place where it may be had in abundance, is very expensive, this, together with various other obvious circumstances, must render any attempt to establish a large iron-manufactory in this village a very hazardous undertaking. No doubt, other kinds of wood might be

found which would yield a charcoal that would answer the purpose sufficiently well; but unluckily all the jungle in the neighbourhood of the village consists of very small brushwood.

"These smelting-works, however, notwithstanding their diminutive scale, attract the attention of every curious observer, on account of the simplicity of every part of the process and the goodness of the iron obtained.

"The furnace consists of a small semi-circular mud wall, very much resembling in shape the half of a hen's egg divided longitudinally, with the largest end uppermost. The wall is built of clay or mud. From the apex to the base is usually 4½ feet, while its greatest breadth is 3 feet 9 inches. The external and convex surface has on one of its sides, at the bottom, an excavation serving to receive the scoriæ, which are let out through a hole in the bottom.

"The internal surface of this mud wall is plain, except a semi-circular excavation throughout its middle part, commencing at the apex and terminating in a circular hole in the ground, which is 1½ feet deep, and as much in diameter. This part corresponds with the square cavity in European furnaces, in which the iron is collected.

"The use of this semi-circular excavation will be understood by considering the temporary part which is destroyed every day after the smelting is finished. It is a thin, convex, semi-circular wall, and is to complete a circular hole with the excavation in the permanent part of the furnace. It is constructed in the following manner:—At 5 o'clock in the evening, the hole in the ground is cleaned from the ashes and the remainder of the last smelting, and its bottom and sides coated with powdered charcoal moistened with a little water. At the bottom, to the right hand, is a small circular hole for letting off the scoriæ. This hole must also be cleaned, and then stopped up with some moistened clay. Charcoal is then thrown into the hole and placed in such a manner that the apex of the heap touches the margin of the hole opposite to the principal work, and another heap of pounded ore is so placed on the opposite side that the middle of the hole is left an empty space. These

two heaps are distant from each other at the apex about a foot, at the bottom about an inch. This is done in order to rest on the charcoal a kind of funnel-formed channel for the admission of the stream of air produced by the constant action of the bellows. The external aperture of the funnel receiving the nozzle of the bellows is in breadth 5 or 6 inches. Clay is then put upon it, which serves both to fix it and to form the first layer of clay that constitutes the temporary part of the furnace. This part is not to be thicker than 2 inches, and it decreases in thickness the higher it advances. The funnel itself is made of a mixture of clay and husks of rice; and previous to its application is hardened by fire, and then made firmer in its position by a coat of clay laid over it.

"The funnel being fixed in this manner, the wall is raised, becoming gradually thinner, so that when it arrives at the middle part, it does not exceed the thickness of an inch. Then a burnt stone of the same thickness, from 10 to 12 inches high and from 8 to 9 broad, is fixed upon it, so that it inclines to the opposite side, the circle becoming narrower the higher it rises. This stone is connected with the principal wall by means of mud. In this manner the circle is completed; some holes of 2 inches square being left, one or two on each side. On the stone itself is placed a second stone of the same kind and shape, but smaller, and fixed in the same manner. Its apex is on a level with the top of the opposite or principal part of the furnace. The top of the furnace now serves as the basis for a cone, the use of which is sufficiently obvious.

"This cone s 12 inches long. Its under-aperture rests on the top of the furnace, where its breadth is 14 inches. At its upper part or apex its diameter is 7 inches. To facilitate the introduction of charcoal and ore into the furnace, the cone is crowned with a large cutcherie pot, the bottom of which is broken out, and thus serves not only to facilitate the introduction of fuel, etc., but is supposed of much consequence as the representation of a swamy.

"It has been already stated that some charcoal and ore had been

placed at the bottom of the furnace, and that the funnel for conveying the wind was placed upon this heap. Some lighted charcoal is put before the opening of the funnel, and the whole cavity is then filled with charcoal, and this is continued as the wall advances in height, the charcoal serving as a support to it, for it is so thin that it would not be able to support its own weight. Within the holes left on each side of the stones, which constitute the middle part of the furnace, some lighted charcoal is also placed.

"The under part of the cone is also filled with charcoal. Then a small basket of ore is thrown upon it, and upon this likewise some lighted charcoal is placed. Finally, the whole cavity is filled up to the top with charcoal.

"Matters are allowed to remain in this state till 5 o'clock next morning, when two pair of bellows are applied to the aperture of the funnel, adapted for the insertion of the nozzles; each pair of bellows is worked by one man. The several vent-holes in the side of the furnace are stopped up with a mixture of clay and sand. The bellows are then worked without intermission, and an intense degree of heat is soon produced.

"The ore is thrown in by small quantities at a time, in small baskets which do not hold above three or four pounds; and for every basketful of ore two basketfuls of charcoal are added. As the charcoal burns the ore gradually sinks downwards, and at last the melted iron and scoriæ make their way to the bottom. The great object of the workmen is to supply the requisite quantity of charcoal and ore, and they continue their additions till within a little of the time when the reduced iron is taken out of the furnace.

"A hole was left ready at the bottom to be opened occasionally in order to permit the scoriæ to run out. This is done regularly every second hour, or six times during the whole operation. They pierce the clay which stops the passage with a pointed iron, suffer the liquid scoriæ to run out, and then secure the hole as before with clay. The cracks produced by the intense heat in the exterior thin wall they take care to

stop up occasionally with moistened clay, and now and then they wet the whole with water in which clay is suspended.

"At five o'clock in the evening the bellows are removed, and the exterior wall of the furnace knocked down. The iron, which is found in a solid state, is taken out and beaten for about five minutes with wooden sticks, in order to separate as much of the scoriæ as possible. Finally, it is cut with axes into two pieces in order to show its internal quality.

"I do not know the precise quantity of iron-stone which is employed in one smelting process. In general, I believe twelve baskets of ore are required, containing each from 4 to 5 computed *mercals*. The whole produce of one process is about 112 lbs. of iron, which are usually sold for about a rupee.

"The iron, as thus produced, is of a very inferior quality, porous, and its pores filled with scoriæ, and in fact a little more than half smelted, if such an expression may be used; for I am persuaded that the whole mass never has been fused, as in that case it would naturally have run out with the scoriæ through the hole at the bottom of the fireplace. The metallic particles in the ore are probably at some distance from each other. The fusion of the scoriæ lays them open to the action of the charcoal. They are reduced to the metallic state, tumble down in consequence of their weight, and, coming in contact with each other at a welding heat, are connected or agglutinated together, without having experienced actual fusion.

"The iron thus obtained is, indeed, of such an inferior quality, that none of the names, by which any of the various kinds of cast-iron are distinguished, can be applied to it. But if it be exposed to the heat produced by urging a fire by a pair of common bellows, while it is quite covered with charcoal, and, when the scoriæ begins to melt, if it be taken out and hammered, it acquires the properties of steel, and may then be usefully employed in the making of instruments."

Other Minerals.—Graphite is rather common, but very sparely distributed among the crystalline rocks along the north-western edge of the field, more particularly perhaps in the neighbourhood of Bezváda,

and again towards the Vizagapatam end of the field, but it is not known to occur in masses of sufficient size or purity to make it worth working otherwise than in the small way required for local demand.

Kondapilli, north of Bezváda, has been long known for its carbuncles or polished garnets; but these are not of much value. They are there washed or picked out from the sands in the neighbourhood of the town, and their original matrix appears to be a band or bands of massive, garnetiferous, hornblendic gneiss, which occur in and alongside the great hill mass from whence this old and once important town takes its name; whence also they are continued to the north-north-east and then northwards into the Chundragunda talúk or division of this eastern portion of the Nizam's dominions.

Coal.—Just outside the north-western edge of the area under description, the field of lower Gondwánas in the neighbourhood of Ashwaraopet possesses an outcrop of coal-bearing strata, which gave some promise of the long-dreamed-of chance of coal in the Madras Presidency; but a series of borings which were put down at Beddadanole, though they struck many seams of more or less coaly matter, showed that none of these were worth working, while the borer appears to have penetrated so near the floor of crystalline rocks on which this patch of Barakar strata lies that there does not seem to be the slightest hope of finding deeper or better seams at this place.[1]

[1] For further particulars of this enquiry, see Rec. Geol. Surv. of India, Vols. V, p. 112, VI., p. 57; and Proceedings of the Madras Government, Public Works Department, December 1873, No. 273; July 1876, &c.